Monographs on
Surgery • 1951

MONOGRAPHS ON SURGERY • 1951

B. NOLAN CARTER, M.D., Ph.D
Editor

Professor of Surgery, University of Cincinnati
Director of the Surgical Services
Cincinnati General Hospital

ADVISORY EDITORS

GYNECOLOGY

JOE V. MEIGS, M.D.,

Clinical Professor of Gynecology, Harvard University Medical School; Chief of the Vincent Memorial Hospital

UROLOGY

CHARLES HUGGINS, M.D.,

Professor of Urology, the University of Chicago, Chairman of Committee on Cancer, the University of Chicago

ORTHOPEDIC SURGERY

ALFRED R. SHANDS, M.D.,

Medical Director, Alfred I. duPont Institute of the Nemours Foundation

THOMAS NELSON & SONS

Toronto NEW YORK Edinburgh

PRINTED IN THE UNITED STATES OF AMERICA

Introduction

As stated in the introduction to the first volume of Monographs on Surgery, its purpose is to present a series of monographs on surgical subjects which are of current interest to the general surgeon as well as to the specialists in the field of Gynecology, Urology, and Orthopedics. Emphasis is to be placed on those subjects about which opinion has crystallized and which rest on a sound foundation of surgical experience and knowledge. The twelve articles in this, the second volume, appear to the editor as fulfilling these purposes.

As Dr. Meigs, Associate Editor for Gynecology, has so aptly stated in his introduction to the Symposium on "Carcinoma in Situ of the Cervix Uteri," this is an outstanding contribution to a subject which is commanding much interest at this time. The contributors to this symposium are the leaders in this field and their cumulative experience is the widest thus far obtainable.

Cholangiography has in recent years developed into an important adjunct to the proper management of biliary tract disease. Drs. Partington and Sachs have presented this subject in a concise and practical manner which should be of considerable assistance to those surgeons who either contemplate utilizing cholangiography or who have already done so.

Diaphragmatic hernia is being more frequently recognized and its management has assumed an increasingly important place in modern surgery. With his wide experience in this field, Dr. Harrington has presented this subject clearly and thoroughly.

One of the real advances in the diagnosis of cancer has been the study of exfoliative cells by various technics. The usefulness of these procedures is unquestioned but they, together with the technical details of the methods utilized, require a thorough evaluation. Drs. Herbut and Rakoff have done this well in their contribution "The Cytologic Diagnosis of Carcinoma."

The part which surgery plays in the management of the nonspecific infections of the intestinal tract, viz., regional ileitis and ulcerative colitis, has been clarified considerably in recent years. Drs. McKittrick and Risley have presented a direct and complete account of the role of surgery in their article "Regional Ileitis and Ulcerative Colitis."

In the field of Urology, Dr. Simmons' interesting article entitled "The Diagnosis and Treatment of the Infertile Male" presents with simplicity a subject which is of importance to the entire medical profession. Drs. Moulton's and Huggins' contribution "The Surgical Management of Prostatic Disease" is concisely written and serves to summarize an attitude toward the surgical treatment of diseases of the prostate gland, with particular reference to carcinoma.

PRINTED IN THE UNITED STATES OF AMERICA

Contributors

1951

Joe M. Blumberg, M.D.: Lt. Col., M.C., U. S. Pathologist, Walter Reed Army Hospital, Army Medical Center, Washington, D. C.

Edwin F. Cave, M.D.: Chief, Fracture Service and Visiting Orthopedic Surgeon, Massachusetts General Hospital; Associate in Orthopedic Surgery, Harvard Medical School, Boston.

Murray M. Copeland, M.D.: Professor of Oncology, Director of Department of Oncology, Georgetown University Medical Center, Washington.

Charles F. Geschickter, M.D.: Professor of Pathology, Georgetown University Medical School; Consultant in Pathology, U. S. Naval Medical School, Bethesda, Md.; Consultant in Pathology, Mt. Alto Veterans Administration Hospital, Pathologist-in-Chief, Gallinger Municipal Hospital, Washington.

Ruth M. Graham: Research Associate in Surgery; Instructor in Cytology, University of Oregon Medical School; Formerly, Research Fellow in Cytology, Massachusetts General Hospital, Boston.

Stuart W. Harrington, M.D.: Division of Surgery, Mayo Clinic, Rochester, Minn.

Peter A. Herbut, M D.: Professor of Pathology, Jefferson Medical College, Philadelphia.

Charles Huggins, M.D.: Professor of Urology, the University of Chicago; Chairman of Committee on Cancer, the University of Chicago, Chicago.

Frank P. Kreuz, Capt., M.C., U.S.N : Chief of the Department of Orthopaedics, U. S. Naval Hospital, National Naval Medical Center, Bethesda, Md.

Leland S. McKittrick, M D.: Clinical Professor of Surgery, Harvard Medical School; Visiting Surgeon, Massachusetts General Hospital; Surgeon-in-Chief, Palmer Memorial Hospital, Boston.

Stanley H. Moulton, M.D.: Instructor in Surgery, Department of Surgery (Urology), University of Chicago, Chicago.

Philip F Partington, M.D.: Assistant Clinical Professor of Surgery, Western Reserve University Medical School; Formerly Chief, Surgical Service, Crile Veterans Administration Hospital, Cleveland.

Edgar R. Pund, M D.: Professor of Pathology, Medical College of Georgia; Chief Pathologist, University Hospital; Consultant Pathologist, Oliver General (U. S Army) Hospital, Augusta, Ga.

Abraham E. Rakoff, M.D.: Clinical Professor of Obstetric and Gynecologic Endocrinology, Endocrinologist, Jefferson Hospital Laboratories, Jefferson Medical College, Philadelphia.

Drs Shands and Kreuz have contributed a complete and practical treatise on "Congenital and Developmental Problems of the Hip in Infants and Childhood" which should prove of particular interest to the orthopedic surgeon and of real interest to the general surgeon. The section on "Bone Tumors" by Drs Geschickter and Copeland deals in a concise fashion with a subject which is of real importance to all surgeons. The material has been clearly presented and the illustrations clarify the text extremely well.

The subject of "Arthrodesis of Joints" has been well presented by Dr. Alan De Forest Smith and is an authoritative discussion of a subject which should prove of general interest.

The ever present and important problem of the management of internal derangements of the knee has been dealt with by Dr. Cave in a comprehensive fashion and is well illustrated.

The accumulation of the volumes as they appear year by year should enable one to do much in the way of keeping abreast of the ever widening surgical literature and of having access to the more important references pertinent to the subjects dealt with in the various volumes.

B. Noland Carter, M.D.

John S. Moore, M.D.: Senior Resident in Orthopaedic Surgery, Hospital of the University of Pennsylvania, Philadelphia.

Alton Ochsner, M.D.: Department of Surgery, School of Medicine, Tulane University of Louisiana; Ochsner Clinic, New Orleans.

Langdon Parsons, M.D., Professor of Gynecology, Boston University School of Medicine; Visiting Surgeon, Massachusetts Memorial Hospital, Boston; Visiting Surgeon, Pondville Hospital, Walpole, Mass.

William W. Scott, Ph.D., M.D.: Professor of Urology, the Johns Hopkins University School of Medicine; Urologist in Charge, the Johns Hopkins Hospital, Baltimore.

Vinton E. Siler, M.D.: Assistant Professor of Surgery, College of Medicine, University of Cincinnati, Attending Surgeon, Cincinnati General Hospital, the Children's Hospital and the Christian R. Holmes Hospital, Cincinnati.

Dana M. Street, M.D.: Chief, Orthopaedic Section, Veterans Administration Medical Teaching Group, Kennedy Hospital, Memphis, Tenn.

John H. Walsh, M.D.: Assistant Resident in Surgery, Cincinnati General Hospital, Cincinnati.

Thomas S Risley, M D. Assistant in Surgery, Massachusetts General Hospital, Clinical Assistant in Surgery, New England Deaconess Hospital, Boston.

Maurice D. Sachs, M D.: Senior Instructor in Radiology, Western Reserve University School of Medicine; Chief, Radiology Service, and Director, Radioisotope Unit, Veterans Administration Hospital, Cleveland.

Alfred R Shands, Jr., M.D.: Medical Director, Alfred I. duPont Institute of the Nemours Foundation, Wilmington, Del.: Visiting Professor of Orthopaedic Surgery, University of Pennsylvania School of Medicine, Philadelphia.

Fred A. Simmons, M.D.· Assistant Surgeon, Massachusetts General Hospital; Instructor in Gynecology, Harvard Medical School, Assistant Surgeon to Outpatient, Free Hospital for Women, Boston

Alan DeF. Smith, M.D.: Professor of Orthopædic Surgery, College of Physicians and Surgeons, Columbia University, Director, New York Orthopaedic Hospital, New York.

Richard W TeLinde, M.D : Gynecologist in Chief, the Johns Hopkins Hospital; Professor of Gynecology, the Johns Hopkins University, Baltimore.

Howard Ulfelder, M D.. Clinical Associate in Gynecology, Harvard Medical School, Assistant Surgeon, Massachusetts General Hospital, Gynecologist, Pondville Hospital, Boston

Paul A Younge, M D.: Instructor, Department of Gynecology, Harvard Medical School, Visiting Surgeon, Free Hospital for Women, Boston

1950

William A. Altemeier, M.D.. Department of Surgery, College of Medicine of the University of Cincinnati, Cincinnati General Hospital, Cincinnati.

Lenox D. Baker, M D : Professor of Orthopaedic Surgery, Duke University School of Medicine, Durham, N C

Leonard F. Bush, M D · Chief of the Orthopaedic Service, Geisinger Memorial Hospital, Danville, Pa

Richard Chute, M D : Associate Visiting Urologist, Massachusetts General Hospital, Assistant in Genito-Urinary Surgery, Harvard University Medical School, Boston

Paul C. Colonna, M.D . Professor of Orthopaedic Surgery, School of Medicine, University of Pennsylvania, Philadelphia.

Michael E DeBakey, M.D.· Department of Surgery, Baylor University College of Medicine, Houston, Tex.

Paul DeCamp, M D.: Department of Surgery, School of Medicine, Tulane University of Louisiana, Ochsner Clinic, New Orleans.

Z. B Freidenberg, M D : Instructor in Orthopaedic Surgery, School of Medicine University of Pennsylvania, Philadelphia.

C Zent Garber, M D . Pathologist, New York Orthopaedic Hospital; Assistant Professor, College of Physicians and Surgeons, Columbia University, New York.

Walter A Hoyt, Jr , M D. Orthopaedic Fellow, National Foundation for Infantile Paralysis; Instructor of Orthopaedic Surgery, Duke University School of Medicine, Durham, N. C.

John S. Moore, M.D.: Senior Resident in Orthopaedic Surgery, Hospital of the University of Pennsylvania, Philadelphia.

Alton Ochsner, M.D.: Department of Surgery, School of Medicine, Tulane University of Louisiana; Ochsner Clinic, New Orleans.

Langdon Parsons, M.D.: Professor of Gynecology, Boston University School of Medicine; Visiting Surgeon, Massachusetts Memorial Hospital, Boston, Visiting Surgeon, Pondville Hospital, Walpole, Mass.

William W. Scott, Ph D., M.D.: Professor of Urology, the Johns Hopkins University School of Medicine; Urologist in Charge, the Johns Hopkins Hospital, Baltimore.

Vinton E. Siler, M.D.: Assistant Professor of Surgery, College of Medicine, University of Cincinnati; Attending Surgeon, Cincinnati General Hospital, the Children's Hospital and the Christian R. Holmes Hospital, Cincinnati.

Dana M. Street, M.D.: Chief, Orthopaedic Section, Veterans Administration Medical Teaching Group, Kennedy Hospital, Memphis, Tenn.

John H. Wulsin, M.D.: Assistant Resident in Surgery, Cincinnati General Hospital, Cincinnati.

Thomas S. Risley, M.D.. Assistant in Surgery, Massachusetts General Hospital; Clinical Assistant in Surgery, New England Deaconess Hospital, Boston.

Maurice D. Sachs, M.D.. Senior Instructor in Radiology, Western Reserve University School of Medicine, Chief, Radiology Service, and Director, Radioisotope Unit, Veterans Administration Hospital, Cleveland.

Alfred R. Shands, Jr., M.D.: Medical Director, Alfred I. duPont Institute of the Nemours Foundation, Wilmington, Del.: Visiting Professor of Orthopaedic Surgery, University of Pennsylvania School of Medicine, Philadelphia

Fred A Simmons, M D.. Assistant Surgeon, Massachusetts General Hospital; Instructor in Gynecology, Harvard Medical School; Assistant Surgeon to Outpatient, Free Hospital for Women, Boston.

Alan DeF. Smith, M.D.: Professor of Orthopædic Surgery, College of Physicians and Surgeons, Columbia University, Director, New York Orthopaedic Hospital, New York.

Richard W. TeLinde, M.D.. Gynecologist in Chief, the Johns Hopkins Hospital; Professor of Gynecology, the Johns Hopkins University, Baltimore.

Howard Ulfelder, M.D.: Clinical Associate in Gynecology, Harvard Medical School, Assistant Surgeon, Massachusetts General Hospital, Gynecologist, *Pondville Hospital, Boston*

Paul A Younge, M.D.. Instructor, Department of Gynecology, Harvard Medical School, Visiting Surgeon, Free Hospital for Women, Boston.

1950

William A Altemeier, M.D.: Department of Surgery, College of Medicine of the University of Cincinnati; Cincinnati General Hospital, Cincinnati.

Lenox D. Baker, M D · Professor of Orthopaedic Surgery, Duke University School *of Medicine, Durham, N C.*

Leonard F. Bush, M.D · Chief of the Orthopaedic Service, Geisinger Memorial Hospital, Danville, Pa.

Richard Chute, M.D.: Associate Visiting Urologist, Massachusetts General Hospital, Assistant in Genito-Urinary Surgery, Harvard University Medical School, Boston.

Paul C Colonna, M D.: Professor of Orthopaedic Surgery, School of Medicine, University of Pennsylvania, Philadelphia

Michael E DeBakey, M.D.. Department of Surgery, Baylor University College of Medicine, Houston, Tex

Paul DeCamp, M.D : Department of Surgery, School of Medicine, Tulane University of Louisiana; Ochsner Clinic, New Orleans.

Z. B Freidenberg, M D : Instructor in Orthopaedic Surgery, School of Medicine University of Pennsylvania, Philadelphia.

C Zent Garber, M.D.: Pathologist, New York Orthopaedic Hospital; Assistant Professor, College of Physicians and Surgeons, Columbia University, New York.

Walter A. Hoyt, Jr., M D : Orthopaedic Fellow, National Foundation for Infantile Paralysis, Instructor of Orthopaedic Surgery, Duke University School of Medicine, Durham, N. C.

Contents

Monographs on
Surgery • 1951

Carcinoma in Situ of the Cervix

JOE V. MEIGS, M.D.

INTRODUCTION

The following five papers constitute the first symposium which it has been my privilege to read on the very earliest types of cervical cancers. The authors are experts in this field of study and their opinions must be considered. The discovery of cancer in situ by Rubin, Schottlander, and Kermauner should be considered an epoch in gynecologic pathology. It has taken many years for the Schiller test, the colposcope, the Papanicolaou vaginal smear test, and cervical biopsy to prove their importance. It is obvious that wider and more intensive use of the tools at our disposal may reduce the numbers of invasive cancers that might be seen in the future. If gynecologic examinations are carried out as they may be and should be, there will be a definite reduction in the numbers of invasive and perhaps inoperable cancers of the cervix. Cervical cancer is being attacked from various angles and the gynecologist now has a real opportunity to discover and cure so many in the early stages that the appearance of this disease in stages III and IV should soon be considered the result of negligence.

Each presentation is slightly different and each writer reports the problem from his or her own angle, but a perusal of these papers leaves the reader with the impression that advances are being made. All these contributors are interested and have written and talked of the problem, and all are hopeful. Te Linde's paper is a report of a long time study of the early lesions and his advice as to diagnosis and treatment is clear and true. Younge, with a large experience, reports cases of invasion developing during study and of pregnancies being watched when cancer in situ was present. Ulfelder shows that our laboratories occasionally change their minds about this lesion and he looks into the future for more satisfactory investigation. Pund has had a vast experience and reports careful observations of many cervices sectioned and studied. He presents new ideas as to the region of origin of the lesion and its local spread. His interest in the endocervix is important to all of us. Mrs. Graham, with her research approach, has picked out a true problem concerning cancer in situ which disappears, and without doubt intends to follow this lead to its conclusion. It would be difficult to group together five more provocative and stimulating papers on a very pertinent subject.

It is obvious to the editor that there is a confusion of names to describe the same thing. This confusion in nomenclature may cause a disinterest on the part of the pathology-minded gynecologist who will be tempted to shut his mind to the problem—this [illegible] Confusion of names, several names for [illegible] may dampen the

GLOSSARY

CANCER IN SITU, PREINVASIVE CANCER, INTRAEPITHELIAL CANCER, INCIPIENT CANCER—These four terms may be considered as synonymous. It is the editor's belief that "cancer in situ" is the most commonly used term and is certainly as descriptive as the other three.

BASAL CELL HYPERACTIVITY, BASILAR HYPERPLASIA—Meaning activity of the palisade-like lower or basal layer of the cervical epithelium. There may be an increase of mitotic figures or an increase in thickness or pegging of the layer due to an increased number of normal cells. It is obvious that more than normal activity is present. This activity does not represent carcinoma but is a warning that further epithelial development may occur.

ANAPLASIA—This term is loosely used to describe cells or groups of cells which are immature or poorly differentiated. Hyperactivity with mitotic figures and irregularity in the size and shape of cells is seen. While these characteristics are associated with cancer, they do not mean cancer because they are also seen in areas of repair, but should be a definite warning.

DYSKARYOSIS, ANISOKARYOSIS—These terms refer to irregularities in growth, size, and conformity of the nuclei such as are seen in malignant and premalignant epithelium.

PARAKERATOSIS—Signifies imperfect keratinization with the large, basal type of nuclei persisting in the superficial epithelial cell layers.

PARALEUKOKERATOSIS—This is a term used to designate an area of parakeratosis in juxtaposition to or surrounded by an area of leukoplakia. It is the benign counterpart of cancers which develop at a leukoplakic junction. Both lesions give a positive Schiller test and must be distinguished by microscopic study.

LEUKOPLAKIA—This is a term referring to a hyperkeratinized, thickly cornified plaque which overlies immature and active epithelium, usually associated with some abnormal basal cell hyperactivity. This lesion gives a positive Schiller test.

KERATINIZATION, CORNIFICATION—Synonymous terms referring to the normal development of a superficial, anuclear layer of cells. This layer may be abnormally thickened, as in leukoplakia or paraleukokeratosis.

EPIDERMIDALIZATION, SQUAMOUS CELL METAPLASIA—Terms meaning a change in the glandular epithelium of the cervix toward the squamous cell type, occasionally confusing and not infrequently diagnosed as epidermoid carcinoma. The cells and nuclei are [illegible] in mitoses. I[illegible] misplaced, is of squamous character and not of a malignant type.

STRATUM GERMINATIVUM—The palisade-like basal layer of the normal cervical epithelium. It is the area from which the rest of the cervical epithelium arises.

enthusiasm of many who should be interested A glossary is appended in an attempt to interpret the various nomenclatures and to group them and make for better understanding. For the sake of the patient and her doctor, simplicity, even though the terminology offends certain investigators, *is more important than* the investigators' sensitivity to names Simplicity in medical writing is important, and avoidance of the more unusual terms found in the histologies and pathologies, in the medical dictionaries, and in the thesaurus is paramount. Word confusion is destructive to understanding.

The question of treatment is a formidable one To the gynecologist, total hysterectomy with the removal of a small vaginal cuff is most satisfactory. No doubt radium, cauterization, conization, repair, amputation of the cervix, the modified Wertheim operation, etc may be carried out, but unless the patient *is to be used in a careful study group, total hysterectomy is the* treatment of choice. Lymph node involvement is rare and, at the present stage of our knowledge, need not be considered.

Invasion should mean a break through the basal epithelium of the cervix and endocervix and a penetration into the stroma of the cervix Invasion of endocervical glands may be invasive but can be considered, as far as treatment is concerned, as still in situ until the tumor breaks through the basement membrane of the gland If invasion is found outside of the gland, the lesion is no longer "in situ," but is invasive cancer and should be treated as such Such lesions, *even though minimal, should not be reported as cancer* in situ Invasion means that the lesion is no longer in situ but has progressed to the actual stage of true cancer. Younge's idea, that as long as there is normal appearing, cornified epithelium on the surface of a typical cancer in situ, it is not cancer in situ, must be further studied. His idea may be a method of separation of cancer in situ from anaplasia, hyperplasia, or overactivity of the lower layers of the epithelium Te Linde's idea of the penetration of cancer into deep glands as evidence of invasion must be studied further and it is obvious that he will eventually know whether this type of invasion means true invasion or not. Mrs Graham's idea of two types of cancer in situ, one in which on vaginal smear the cells resemble true invasive cancer, and the other the type with the single, differentiated cell, may divide these lesions into those that must be treated and those that should be studied Pregnancy certainly confuses the issue and studies are in progress that should clarify this situation.

In this symposium nearly 645 patients with cancer in situ have been reported This is an enormous number and it shows that if five groups can report this number that there must be many more than could be located and included in the obviously benign cancer in situ group Painstaking clinical appraisal of the gynecologic patient will produce more cures and prevent more deaths from cervical cancer than all the radiation and surgery that can be given to or done on patients.

GLOSSARY

CANCER IN SITU; PREINVASIVE CANCER, INTRAEPITHELIAL CANCER, INCIPIENT CANCER—These four terms may be considered as synonymous. It is the editor's belief that "cancer in situ" is the most commonly used term and is certainly as descriptive as the other three

BASAL CELL HYPERACTIVITY, BASILAR HYPERPLASIA—Meaning activity of the palisade-like lower or basal layer of the cervical epithelium. There may be an increase of mitotic figures or an increase in thickness or pegging of the layer due to an increased number of normal cells. It is obvious that more than normal activity is present. This activity does not represent carcinoma but is a warning that further epithelial development may occur.

ANAPLASIA—This term is loosely used to describe cells or groups of cells which are immature or poorly differentiated. Hyperactivity with mitotic figures and irregularity in the size and shape of cells is seen. While these characteristics are associated with cancer, they do not mean cancer because they are also seen in areas of repair, but should be a definite warning.

DYSKARYOSIS; ANISOKARYOSIS—These terms refer to irregularities in growth, size, and conformity of the nuclei such as are seen in malignant and premalignant epithelium.

PARAKERATOSIS—*Signifies imperfect keratinization with the large, basal type of* nuclei persisting in the superficial epithelial cell layers.

PARALEUKOKERATOSIS—This is a term used to designate an area of parakeratosis in juxtaposition to or surrounded by an area of leukoplakia. It is the benign counterpart of cancers which develop at a leukoplakic junction. Both lesions give a positive Schiller test and must be distinguished by microscopic study.

LEUKOPLAKIA—This is a term referring to a hyperkeratinized, thickly cornified plaque which overlies immature and active epithelium, usually associated with some abnormal basal cell hyperactivity. This lesion gives a positive Schiller test.

KERATINIZATION, CORNIFICATION—Synonymous terms referring to the normal development of a superficial, anuclear layer of cells. This layer may be abnormally thickened, as in leukoplakia or paraleukokeratosis.

EPIDERMIDALIZATION; SQUAMOUS CELL METAPLASIA—Terms meaning a change in the glandular epithelium of the cervix toward the squamous cell type, occasionally confusing and not infrequently diagnosed as epidermoid carcinoma The cells and nuclei are regular and normal appearing and lacking in mitoses. It should be obvious from a glance that this epithelium, although misplaced, is of squamous character and not of a malignant type.

STRATUM GERMINATIVUM—The palisade-like basal layer of the normal cervical epithelium. It is the area from which the rest of the *cervical epithelium* arises.

STRATIFICATION—Layers of cells lying on or above one another of the same or of different types

ECTROPION—Exposure of the endocervix. A bulging forth of the glandular epithelium following abnormal development or laceration.

CONGENITAL EROSION OF THE CERVIX—The five to twenty-five-cent-piece-sized red area about the external os so often seen in young women. It denotes a lack of normal development of the cervix as this red exposed epithelium is glandular and should be up inside of the cervical canal, constituting part of the endocervix It is a congenital maldevelopment and exposes glandular epithelium to contact with the vagina.

RESERVE CELLS—A term used by Pund to describe cells that are in the basal layers of the epithelium of the cervix at the junction of the squamous and glandular epithelium. These cells may progress to form glandular epithelium or may progress to squamous epithelium

STAGE 0—The new stage added to the International Classification of Cervical Cancer Stage 0 represents cancer in situ, preinvasive cancer, intra-epithelial cancer, and incipient cancer.

Carcinoma in Situ of the Cervix

RICHARD W. TE LINDE, M.D.

There are three fundamental questions regarding carcinoma in situ which require answers. These answers should be based on sound histologic and clinical evidence and a correlation of the two.

(1) What is carcinoma in situ?

(2) What is the relation between carcinoma in situ and invasive cervical cancer?

(3) How should the condition be treated?

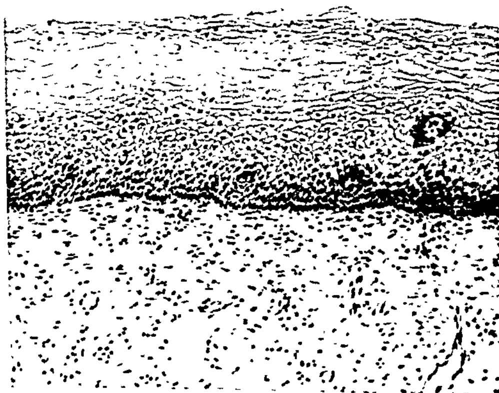


FIG. 1.—Normal cervical epithelium, showing typical stratification of epithelial cells

In this review of the subject I shall attempt to answer these three questions according to our present light, based chiefly on our own experience and to some extent on that of others. Within the last decade sufficient evidence has been accumulated to crystallize our ideas on many phases of this subject which is not

STRATIFICATION—Layers of cells lying on or above one another of the same or of different types

ECTROPION—Exposure of the endocervix. A bulging forth of the glandular epithelium following abnormal development or laceration.

CONGENITAL EROSION OF THE CERVIX—The five to twenty-five-cent-piece-sized red area about the external os so often seen in young women. It denotes a lack of normal development of the cervix as this red exposed epithelium is glandular and should be up inside of the cervical canal, constituting part of the endocervix. It is a congenital maldevelopment and exposes glandular epithelium to contact with the vagina.

RESERVE CELLS—A term used by Pund to describe cells that are in the basal layers of the epithelium of the cervix at the junction of the squamous and glandular epithelium. These cells may progress to form glandular epithelium or may progress to squamous epithelium

STAGE 0—The new stage added to the International Classification of Cervical Cancer Stage 0 represents cancer in situ, preinvasive cancer, intra-epithelial cancer, and incipient cancer.



Fig. 2.—Typical examples of carcinoma in situ.

only of scientific interest but also of great practical importance in helping us attack the momentous problem of cervical cancer.

The first question—what is carcinoma in situ?—will be answered briefly and then the microscopic evidence to support this definition will be presented. *Carcinoma in situ is a term which should be applied to a microscopic picture of the surface cervical epithelium in which the individual cells through the full thickness of the epithelial layer have the same characteristics as those of invasive cancer.* As a point of departure the microscopic picture of the normal cervical epithelium should be reviewed Figure 1 is a typical section On the basement membrane, immediately adjacent to the fibromuscular stroma of the cervix, is a layer of fat spindle cells, the nuclei of which are oval and take a deep hematoxylin stain. The cytoplasm of these cells also stains lightly with hematoxylin Just superficial to these cells there usually is a layer or two of cells which stain lightly basophilic. As one progresses toward the surface the cells become polyhedral. The nuclei still stain with hematoxylin but the cytoplasm takes a light eosin stain. Still more superficially the cells become flattened and although the nuclei stain with hematoxylin the cytoplasm stains rather deeply pink. The most superficial cells are completely flattened and keratinized. In short, there is a gradual transition in form and staining qualities between the perpendicular basal spindle cells and the transversely flattened superficial cells In carcinoma in situ there is a complete absence of this stratification. The individual cells vary in size and shape and the nuclei, which are also variable in form, tend to be larger in relation to the cells than those of the normal cells. Many of the nuclei stain heavily with hematoxylin, and mitotic figures are frequent. This microscopic picture if seen in the depth of the cervix or in a metastatic position would mean cancer to the eye of any pathologist Figure 2 illustrates typical examples. The transition between carcinoma in situ and normal cervical epithelium is often abrupt. The line of demarcation may be perpendicular as in Fig. 3 or oblique as in Fig 4 When the transition is sudden the diagnosis is obvious but not infrequently there is a gradual transition between the hyperactive looking abnormal cells in the lower epithelial layers and the normal superficial cells Figure 5, for example, shows only hyperactive looking cells in the basal layers, whereas the upper layers of the epithelium retain normal stratification, the cells being entirely regular and benign in appearance Figure 6 shows a much higher degree of involvement of the epithelium with hyperactive cells but the transition from abnormal to normal cells is gradual, the greatest degree of nuclear activity being in the depths of the epithelium and the superficial cells appearing perfectly benign. When the entire thickness of the epithelial layer is taken over by the abnormal hyperactive cells the condition becomes, by definition, carcinoma in situ We have chosen to call the hyperactive process, when limited to the deeper portions of the surface epithelium, "basal cell hyperactivity." Since there appear to be all degrees of this abnormal cellular activity, differences of opinion regarding its significance will naturally arise We have attempted to learn the relation between basal cell hyperactivity and carcinoma in situ by following patients showing this abnormality over a period of several months but we confess that we have not found the absolute answer. In some instances definite basal hyperactivity has been found at biopsy when subsequent biopsies after many months have revealed only normal cervical epithelium. This

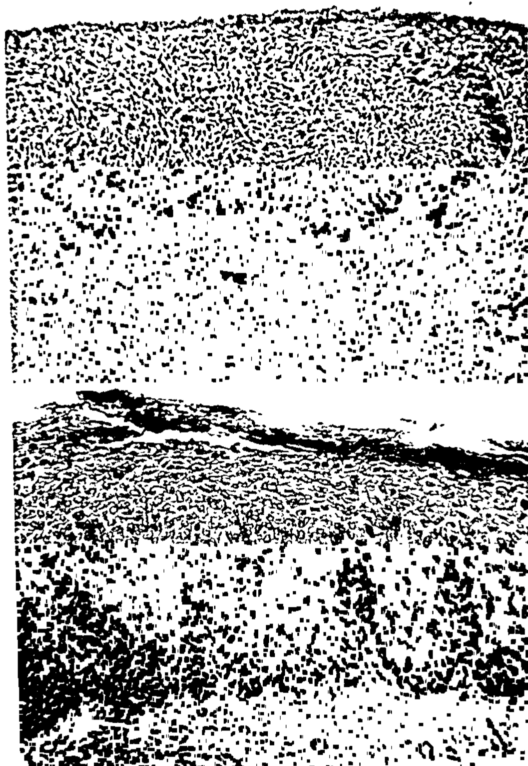


Fig. 2.—Typical examples of carcinoma in situ.



FIG. 3.—Showing perpendicular line of demarcation between carcinoma in situ and normal epithelium



FIG. 4.—Showing oblique line of demarcation between carcinoma in situ and normal epithelium

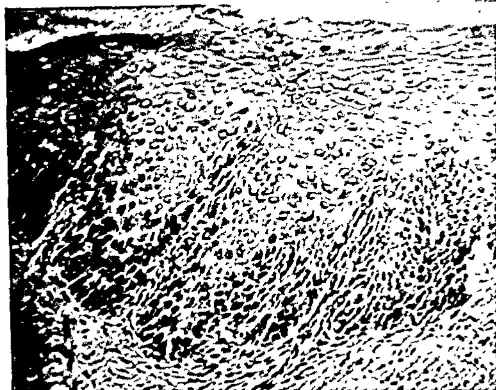


Fig. 5 —Slight basal cell hyperactivity. Biopsy Jan. 8, 1947.

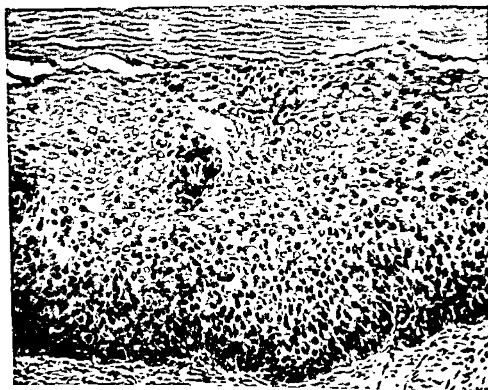


Fig 6 —Higher degree of basal cell hyperactivity. Biopsy Jan. 20, 1947.



FIG 3 —Showing perpendicular line of demarcation between carcinoma in situ and normal epithelium



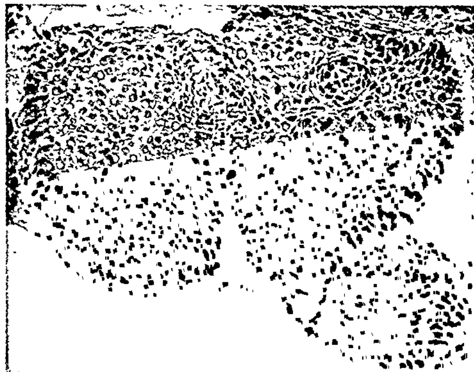
FIG 4 —Showing oblique line of demarcation between carcinoma in situ and normal epithelium.

suggests the possibility that the process *may* be reversible at an early stage. On the other hand, we have in some instances taken successive biopsies from cervices from which the first one showed only basal cell hyperactivity and later ones have shown typical carcinoma in situ and even invasive cancer. Figure 5 shows a biopsy taken January 8, 1947. Figure 6 shows another biopsy from the same cervix taken January 20, 1947 showing more marked basal cell hyperactivity. On October 9 of the same year another biopsy was taken. This is shown in Fig. 7. The abnormal cells occupy the full thickness of the epithelium and a diagnosis of intra-epithelial cancer was made. A modified Wertheim total abdominal hysterectomy was done at that time and the cervix was cut into many blocks. Figure 8 shows plugs of invasive cancer found on sectioning the entire cervix. It is certain that basal cell hyperactivity is often found in the proximity of true carcinoma in situ and even near invasive cancer. We are inclined to regard the microscopic finding of basal cell hyperactivity as a warning and to follow the patient carefully for months with repeated biopsies. If subsequent biopsies are still indefinite a sharp conization of the cervix with cutting of the entire cone into blocks and making many sections of the several blocks will usually confirm or reject the suspicion of malignancy.



FIG 9 —Epidermidalization.

The microscopic description of carcinoma in situ would not be complete without calling attention to a lesion which is sometimes confused with it. We refer to epidermidalization or squamous cell metaplasia This condition is found in many chronically infected cervices and especially in cervical polyps. Replacing the columnar epithelium on the surface and in the depths of the glands is multi-



..iopsy Oct 9, 1947



.. ..ie cervix following hysterectomy.

attempt to answer our second question regarding the relation of carcinoma in situ to invasive cervical cancer.

Schottländer and Kermauner first described the microscopic picture of intraepithelial cervical cancer in 1912. It was discovered extending over the surface of the cervix surrounding advanced cervical carcinoma. They considered it a method of extension of the mature malignant growth. In the 1930's Schiller published many articles suggesting that cervical cancer might begin as a surface lesion and even extend over a considerable area and remain on the surface for some time before eventually invading the subjacent stroma. He presented some clinical evidence to support his views that this surface lesion was actually early cancer, such as deaths with recurrence following total hysterectomy for lesions which were thought to be in situ.



FIG. 11.—Benign epidermidalization with pearl formation. The patient was well for 20 years after removal of a polyp.

In 1939 Galvin and Te Linde undertook a histologic study on cervices that had been removed following a biopsy diagnosis of carcinoma in situ. The patients were treated by total hysterectomy so that the entire uterus was available for study. The removed cervices were cut up completely in blocks and many sections made of each block in a search for microscopic invasive cancer. In a total of 108 cases, microscopic invasive cancer was found 72 times. It is only fair to say that there is often some difference of opinion as to what constitutes invasion. We have included in the above invasive cases some in which the "invasion" was limited to the lumina of glands. It appears that frequently the surface lesion first enters the depths of the cervix by traveling along the glandular lumina destroy-

layered squamous-like epithelium The cells are often vacuolated and otherwise atypical but do not contain the hyperchromatic nuclear changes and mitoses seen in intra-epithelial cancer. Although greatly distorted, some semblance of stratification of the atypical cells remains The description is best made by photomicrographs, such as shown in Figs 9 and 10. Replacement of all of the columnar epithelium of glands is not uncommon and the picture may be suggestive of invasion but careful examination under high power magnification of the individual cells will exclude malignancy. In some instances even epithelial pearls are present



Fig. 10 —Epidermidalization Note the semblance of stratification of the epithelial cells.

(Fig 11). The final differentiation, as in all malignancy, is made by clinical follow-up of women showing this condition. The author has done this over several years and has found no evidence that these lesions eventuate in malignancy. Uncertain pathologists have straddled in their decision by calling such lesions precancerous but there is no evidence that they bear any relation to cancer.

The above descriptions represent our conception of the microscopic picture of carcinoma in situ but the histologic conception means nothing unless the relation of this picture to true cervical cancer can be proved. Hence, we shall

ing the epithelium as it progresses (Figs. 12 and 13). All gradations of this progress can be seen. When the glandular lumina are completely filled and the columnar epithelium entirely destroyed, we have what appear to be plugs of deep lying carcinoma beneath the surface, the invasive nature of which cannot be disputed (Fig. 14). Figure 15 is a low power section of the anterior cervical lip of a grossly normal appearing cervix. The surface is covered with typical intra-epithelial cancer up to the point indicated by the arrow. Well below the surface are many islands of invasive cancer. Under higher magnification it can



FIG. 14 —Invasive cancer, probably resulting from destruction of glands. Note the remnant of columnar epithelium remaining in the carcinoma plug in the center of the picture.

be seen that some of these plugs of cancer have remnants of normal columnar glandular epithelium. Since all gradations of this process of glandular destruction are seen innumerable times, Galvin and Te Linde were forced to the conclusion that glandular invasion is frequently the first step in the true invasive process. Of the 108 cases there were 20 in which further carcinoma in situ was found in the removed cervices and in 16 no further carcinoma of any kind was found.

From Schottlander and Kermauner's original work and the above cited work of Galvin and Te Linde it is evident that the finding of carcinoma in situ in a biopsy may indicate three possibilities:



Fig. 12 —Invasion of gland by intra-epithelial carcinoma



Fig 13 —Glands being invaded and destroyed by ingrowing carcinoma.

that the clinical life of a cervical cancer is only a short span in its entire life. It is possible that some women who have the in situ lesion die from other causes before ever developing clinical cancer. The possibility of carcinoma in situ existing for years in a subclinical stage is borne out by the fact that the average age of women with carcinoma in situ is in the neighborhood of 36 or 37, a full decade before the average age of women with clinical cervical cancer.

The proper treatment of these microscopic lesions must be based on sound knowledge of pathology. It seems evident that since in many instances we are dealing with microscopic invasive cancer the lesions cannot be considered too lightly from a standpoint of therapy. Galvin and Te Linde started treating these lesions 10 years ago by total abdominal hysterectomy. Although the number of *patients who were operated on five years ago is small, all of them are well.* A total of 99 women has been treated surgically during the decade and 9 by irradiation. These were irradiated chiefly because they were considered poor surgical risks although 2 of them represent instances of accidental findings in cervices amputated in the course of a Manchester operation. In these 2 instances the shortened cervix was irradiated. The only death occurring in the entire series of 108 was in a patient who had been treated by irradiation. It is interesting that recurrence was noted soon after the treatment and she died within six months, with metastatic cancer found at necropsy. All of the 99 women on whom hysterectomy was performed are living and well. In most of these the interval since operation has been less than five years so these results cannot be regarded as statistically significant. In several of the young women we have saved an ovary. These women have remained well and we have no cause to believe that this should not be done in this type of early malignancy. The ovary is a site of late metastasis in cervical cancer and it seemed unlikely to us that in these extremely early cases removal of the ovary would be necessary. Our results with surgery have been so satisfactory that we see no reason for changing our line of therapeutic attack on this problem

The hysterectomy which we perform is a little more extensive than the usual one for benign disease. About 2 cm. of parametrial tissue are removed on either side and, probably most important of all, a cuff of vagina of about 1 cm. is removed with the cervix. We believe this is important because in some instances the noninvasive carcinoma is quite extensive, reaching almost to the vagina, even when the cervix appears grossly normal. The operation is simplified and made safer by the preoperative passage of ureteral catheters. In this way the operator can fearlessly and safely clamp the parametria at a distance from the cervix by frequently palpating the catheterized ureters. We have had no ureteral injuries by utilizing preoperative catheterization and feel convinced that much operative time has been saved.

In some clinics this condition has been treated by cervical amputation and even conization Our histologic experience in studying the removed cervices would indicate that these procedures are not sufficiently radical to remove all of the carcinoma. Some workers in this field have advocated cervical amputation fol-

[illegible] inva-

[illegible] ...d out.

[illegible] is no doubt that such a procedure will result in a high percentage of cures

(1) That the biopsy was taken from the periphery of an advanced cervical cancer, as originally described by Schottlander and Kermauner.

(2) That microscopic invasive cancer is present elsewhere in the cervix (in 68.5 per cent of the 108 cases).

(3) That only carcinoma in situ is present. However, the findings of Galvin and Te Linde would indicate that the chances of invasive cancer being present in the cervix are considerable.



FIG 15.—Low power section of anterior lip of the cervix Surface epithelium of carcinoma in situ to right of the arrow Note the invasive cancer on the extreme right

It appears that little, if any, more information regarding the relation between surface and invasive cancer can be gained from simple histologic study. Nevertheless, clinical studies offer further possibilities. Such studies began with the evidence presented by Schiller in 1938 when he reported one recurrence after five years and 2 recurrences before the lapse of five years following hysterectomy for what was considered from the biopsy to be carcinoma in situ. Galvin and Te Linde report one death following irradiation for this condition. The death occurred six months after treatment and necropsy showed metastatic cancer.

In addition to this evidence supporting the relationship of carcinoma in situ to advanced cervical cancer, there are now reported in the literature approximately 30 authentic cases of advanced cervical cancer appearing in cervices previously biopsied and where carcinoma in situ was found but left untreated The lapse of time between the original biopsy and the appearance of advanced cancer has varied between several months to 12 years It thus seems probable

that the clinical life of a cervical cancer is only a short span *in its entire life.* It is possible that some women who have the in situ lesion die from other causes before ever developing clinical cancer. The possibility of carcinoma in situ existing for years in a subclinical stage is borne out by the fact that the average age of women with carcinoma in situ is in the neighborhood of 36 or 37, a full decade before the average age of women with clinical cervical cancer.

The proper treatment of these microscopic lesions must be based on sound knowledge of pathology. It seems evident that since in many instances we are dealing with microscopic invasive cancer the lesions cannot be considered too lightly from a standpoint of therapy Galvin and Te Linde started treating these lesions 10 years ago by total abdominal hysterectomy. Although the number of patients who were operated on five years ago is small, all of them are well. A total of 99 women has been treated surgically during the decade and 9 by irradiation. These were irradiated chiefly because they were considered poor surgical risks although 2 of them represent instances of accidental findings in cervices amputated in the course of a Manchester operation. In these 2 instances the shortened cervix was irradiated. The only death occurring in the entire series of 108 was in a patient who had been treated by irradiation. It is interesting that recurrence was noted soon after the treatment and she died within six months, *with metastatic cancer found at necropsy.* All of the 99 women on whom hysterectomy was performed are living and well. In most of these the interval since operation has been less than five years so these results cannot be regarded as statistically significant. In several of the young women we have saved an ovary. These women have remained well and we have no cause to believe that this *should not be done in this type of early malignancy. The ovary is a site of late* metastasis in cervical cancer and it seemed unlikely to us that in these extremely early cases removal of the ovary would be necessary. Our results with surgery have been so satisfactory that we see no reason for changing our line of therapeutic attack on this problem.

The hysterectomy which we perform is a little more extensive than the usual one for benign disease About 2 cm. of parametrial tissue are removed on either side and, probably most important of all, a cuff of vagina of about 1 cm. is removed with the cervix We believe this is important because in some instances the noninvasive carcinoma is quite extensive, reaching almost to the vagina, even when the cervix appears grossly normal. The operation is simplified and made safer by the preoperative passage of ureteral catheters. In this way the operator can fearlessly and safely clamp the parametria at a distance from the cervix by frequently palpating the catheterized ureters. We have had no ureteral injuries by utilizing preoperative catheterization and feel convinced that much operative time has been saved.

In some clinics this condition has been treated by cervical amputation and even conization. Our histologic experience in studying the removed cervices would indicate that these procedures are not sufficiently radical to remove all of the carcinoma. Some workers in this field have advocated cervical amputation followed by a careful and complete histologic study of the amputated cervix. If invasion is found the patient is irradiated; if not, no further treatment is carried out. There is no doubt that such a procedure will result in a high percentage of cures

but it seems to us to be a good surgical principle to perform an operation which completely removes a malignant lesion if it is to be attacked surgically. To illustrate our point of view, Fig. 16 is a low power illustration of the entire lip of a cervix. The low epithelium shown in the picture is carcinoma in situ and only intra-epithelial cancer was seen in the original biopsy. However, well up in the cervical canal two plugs of invasive cancer were found. Figure 17 shows one of these plugs under high power magnification. Had this cervix been amputated, the amputation would have been done directly through or dangerously near this carcinomatous tissue. Our collection of histologic material includes a number of similar cases.



Fig 16.—Low power section of lip of the cervix The low surface epithelium is carcinoma in situ Note the two epithelial plugs on the extreme right.

In performing total hysterectomy in this early lesion it is probable that we have carried out this major procedure in some instances where lesser surgery would have sufficed to cure the patient However, this appears to us to be a minor objection when dealing with a lesion which has lethal possibilities.

An important question on which it would be desirable to have unanimity of opinion concerns the classification and name of these lesions. Carcinoma in situ can be descriptive of only one microscopic field, whereas the entire lesion of the cervix may include some invasive cancer and it may be reasonably extensive, even though the cervix appears normal For classification within this special group it is a requisite that the lesion cannot be diagnosed as cancer grossly. If these microscopic lesions are classified as League of Nations stage I it is obvious that the over-all percentage of cure in the League of Nations Group stage I will be greatly increased *Statistics acquired in this way will simply not be comparable*

with those of previous years. It would seem therefore, that these lesions should be classified separately. Since any name that is really descriptive would be cumbersome it is proposed that they be designated as Stage 0 and that statistical data be kept on them under that heading so that we may ultimately learn the best therapeutic attack.

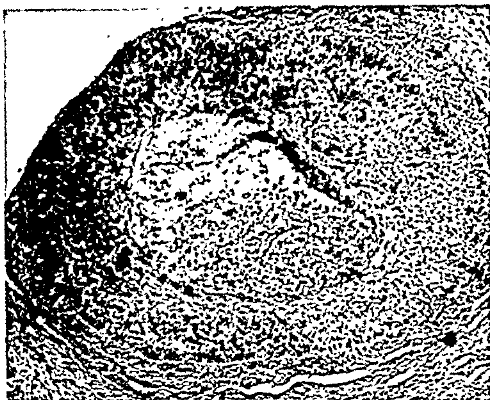


Fig. 17.—Higher power view of a plug from the section shown in Fig. 16, showing it to be invasive cancer.

Carcinoma in Situ of the Cervix

PAUL A. YOUNGE, M.D.

HISTORY

To the author's mind there is no question that definite squamous cell carcinoma in situ of the cervix is the early stage of invasive cancer. The emphasis which he wishes to make is that the earlier stages of carcinoma in situ (anaplasia) can be treated conservatively and that there is ample time to evaluate the extent of the disease even in the unequivocal cases before radical therapy is instituted.

Isadore C. Rubin, in 1910, described carcinoma in situ of the cervix for the first time in the American literature. He called it "incipient carcinoma." Later, in 1918, referring to 1 of the 3 cases he had reported previously he stated that the pathologic examination "demonstrated the carcinoma in situ." Broders of the Mayo Clinic is usually given credit for coining the term "carcinoma in situ" when he described early cancer of the skin in 1932 Since this term accurately describes the pathologic lesion, implies that it is the early noninvasive stage of definite malignancy, and is equally applicable to early malignancy of glandular epithelium, it would seem appropriate to use this term exclusively.

During the past 10 years, the concept that squamous cell carcinoma in situ of the cervix is actually the early stage of invasive cervical cancer has been accepted fairly widely by both gynecologists and pathologists Ten to 20 years ago, most of the reported cases were incidental findings after hysterectomy for some other reason. In addition, there were a few reported cases in which carcinoma in situ was found on re-examination of an earlier cervical biopsy from patients who later developed invasive and clinically obvious cancer. These latter cases are the keystone of the present day concept; yet to date no more than 25 such cases have been reported in which carcinoma in situ progressed to frank cancer of the cervix These observations, however, lead to more frequent routine biopsy of benign appearing cervical lesions which has greatly increased the number of cases studied during the past 10 years. For the most part, all of the literature on this subject concerns itself with the histologic and cytologic aspects of the condition. Judging from the discussion elicited by recent papers any attempt to treat this disease conservatively is severely criticized because it is now generally accepted to be truly early carcinoma, and, therefore, must be treated as such.

DIAGNOSIS

Although most pathologists now recognize carcinoma in situ of the cervix, little is known about its life history, rate of growth, the stage at which stromal invasion takes place, when metastasis occurs, and even whether or not it is an irreversible

process. Also, opinions differ as to what histologic picture constitutes actual stromal invasion. In 1937, Dr. Shields Warren disagreed with our diagnosis of carcinoma in situ because of the absence of invasion in a biopsy specimen which showed replacement of the glandular epithelium by the noninvasive carcinoma (glandular involvement). Yet one year later serial sections of this cervix revealed definite unequivocal invasion at the same location (Figs. 1 and 2). In 1949, Galvin and Te Linde reported 75 cases of cervical carcinoma in situ of which 55 showed invasion after thorough study. To us, the invasion in their illustrated cases is merely glandular involvement which Doctor Warren would not accept as malignancy 13 years ago. This is merely an example of the state of flux or even possible confusion which still exists. More carefully controlled clinical experiments must be conducted to clarify the issue because the disease is being found more and more frequently in young women whose reproductive ambitions have not been realized fully and also because at the present time the detection and treatment of cervical cancer in the in situ stage is the only way to be able to cure 100 per cent of the cases.

Great advance has been made in the more universal recognition of carcinoma in situ of the cervix in the past 20 years. There is, however, more than suggestive evidence that the pendulum has swung too far. Many young women are being sterilized by irradiation or hysterectomy for alleged carcinoma in situ when the process actually is merely anaplasia which we suspect may be a reversible stage in the development of cancer depending on the influence of some unknown factors. We are seeing an increasing number of patients with anaplasia of the cervix and Papanicolaou smears positive for cancer in whom the anaplasia regresses, and the cytologic picture of cancer disappears. These cases are examples of the squamous epithelium of the cervix becoming almost malignant but regressing to normal as the result of the reparative process stimulated by the trauma of biopsy, the decrease in the intensity of local, chronic infection, improvement in general health by diet (vitamins), changes in hormonal balance, or by the disappearance of some unknown carcinogenic substance such as a virus or enzyme.

The important practical problem of the moment is to re-evaluate the criteria for the diagnosis of carcinoma in situ and try to point out the type of histologic picture which represents inevitable invasion and metastasis as well as the type which may be a reversible anaplasia, that is, one which may be treated conservatively or just followed without any treatment until the pendulum swings one way or the other As will be demonstrated, some anaplasias regarded by competent pathologists as carcinoma in situ may regress without treatment other than punch biopsy. Also, evidence is slowly being accumulated to suggest that pregnancy of itself does not influence the progress of anaplasia.

Can carcinoma in situ of the cervix be cured by conservative measures? Is it safe to attempt conservative, nonsterilizing treatment? Can invasive cancer be ruled out by multiple biopsies? Should all cases of carcinoma in situ of the cervix be treated by hysterectomy, and, if by hysterectomy, should it be simple or radical? These are questions which must be answered, and we believe we can from our experience with this disease at the Free Hospital for Women.

To re-evaluate the criteria for the diagnosis of definite carcinoma in situ we must go back to the now historical cases in which this condition was followed by



FIG. 1—Specimen from a case of classic carcinoma in situ of the cervix with glandular in- [illegible]



FIG. 2—The same site from which the original biopsy seen in Fig 1 was taken, but 12 months later, showing the entire squamous carcinoma measuring approximately 5 mm. in diameter. Note the invasive lesion in the center, glandular involvement on the left, and normal surface *portio epithelium on the right* This *emphasizes* the site at which most carcinomas *in situ* originate in the cervix

(Younge, P. A, Hertig, A T., and Armstrong, D: *Am J. Obst & Gynec.*, 58 867, 1949.)

clinically invasive cancer of the cervix. Unfortunately those cases are in reality few in number, but they are the only unquestionable proof of the validity of this concept. The original biopsy specimens in those cases all showed complete absence of surface differentiation. The entire thickness of the noninvasive, malignant-appearing epithelium was composed of undifferentiated, hyperchromatic, pleomorphic cells in a disorderly arrangement with mitoses in all layers. In most, if not all of the cases, this malignant surface epithelium extended into the mouth of the cervical glands and in some cases entirely replaced the glandular epithelium. The microscopic appearance of this noninvasive, malignant epithelium is obvious by low power magnification. It is not necessary to use high power or oil immersion lenses to search for mitotic figures because their presence is obvious in all layers, and the absence of differentiation is readily evident. Figure 1 shows the original biopsy specimen in a deliberate clinical experiment. One year later there was definite stromal invasion (Fig. 2), but it was still an asymptomatic lesion only 5 mm. in diameter at the site of the original biopsy. At the time of the original biopsy tissue from other areas of the cervix consisted of normal squamous epithelium, but later when the carcinoma in situ had become invasive the remainder of the cervix showed anaplasia, or basal hyperactivity of the deeper half of the epithelial layer.

Figure 3 shows a definite and unequivocal case of carcinoma in situ of the cervix which represents a more malignant variety of the disease which is infrequently seen. This case showed extreme epithelial unrest because, in addition, there was carcinoma in situ of the endocervix as well as of the endometrium. This case probably would have developed a grade III or grade IV squamous cell

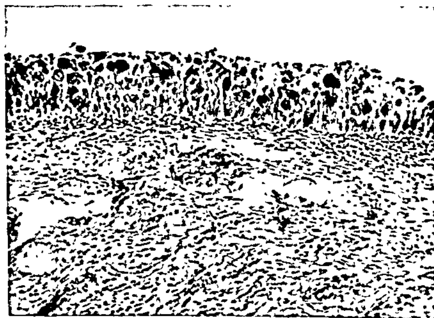


FIG 3 —Specimen from a case of extensive neoplasia of the uterus, having squamous cell carcinoma in situ of the cervix and adenocarcinoma in situ of the endocervix and endometrium (S-39-2450). The above section, showing complete lack of differentiation and marked pleomorphism, is taken from the *symptomless* erosion on the portio of the cervix. The patient, 39 years of age, had been pregnant 14 times with 10 full term deliveries and 4 miscarriages. She was examined because of stress incontinence



Fig 1 –Specimen from a case of classic carcinoma in situ of the cervix with glandular involvement leading to invasive squamous carcinoma at the site of the original biopsy 12 months later (Path No 27434) Original biopsy from "11 o'clock" on anterior lip of the cervix Note the lack of surface differentiation, mitotic figures above basal layer pleomorphism, and hyperchromatism of nuclei grown into

(Younge, P A, He 7, 1949)



Fig 2 –The same site from which the original biopsy seen in Fig 1 was taken, but 12 months later, showing the entire squamous carcinoma measuring approximately 5 mm in diameter Note the invasive lesion in the center, glandular involvement on the left, and normal surface portio epithelium on the right This emphasizes the site at which most carcinomas in situ originate in the cervix

(Younge, P A, Hertig, A T, and Armstrong, D · *Am J Obst & Gynec*, 58.867, 1949)

involvement only). The remainder of the cases showed replacement of part or all of the columnar cells in some or all of the glands in the involved area of the cervix (*glandular involvement*).* Invasion of the stroma may occur either from the surface or from the involved glands. A microscopic section which includes just the edge of an involved gland mouth but does not show the gland deep in the cervix may suggest or be mistaken for early stromal invasion from the surface. Likewise when glands are completely replaced by carcinoma in situ they too may suggest nests of invasive cancer beneath the surface, but serial sections can demonstrate their continuity with the surface.



FIG. 5 – Same case (S-49-1706) as in Fig 4 This shows extension of the surface cancer into glands and possible early stromal invasion on the right side.

The sections of a biopsy which show a scalloped, basal border resembling numerous downward growing buds into the stroma (Fig. 6) may appear to be a carcinoma in situ, but not infrequently it represents the "surface coating" at the periphery of an invasive cancer. This was first described by Kermauner, in 1912, and is frequently referred to as the Kermauner phenomenon. It is important, therefore, in all patients from whom the original set of biopsies show carcinoma in situ to re-biopsy and curet the cervical canal in order to rule out invasive cancer. If the diagnosis is confirmed and no more than glandular involvement is found, a simple total hysterectomy with or without oophorectomy should be performed. The amount of vaginal cuff which should be removed with the cervix can be determined immediately preceding the hysterectomy by the Schiller test. In the great majority of the cases observed the vagina itself is not involved so that the extreme shortening of the vagina is seldom justified. It must be remembered, however, that carcinoma in situ has been seen to involve the

* Glandular involvement (endocervical) should never be confused with lymph node involvement, yet how many of us still use the incorrect term "lymph gland"?

carcinoma of the cervix had not a hysterectomy been performed when it was still in the in situ stage. Most of the bona fide cases of carcinoma in situ of the cervix are similar to the one pictured in Fig. 1 which represents the early stage of the more common grade II cancer

The case represented by Figs 4 and 5 was asymptomatic, and the hysterectomy was performed because of positive Papanicolaou smears. Two sets of cervical biopsies performed without the help of the Schiller test showed only anaplasia, and no endocervical curettage was performed. Neither biopsy obtained endocervical epithelium, demonstrating that they had been taken improperly. In Fig 4 will be seen in one field definite carcinoma in situ in between two areas of anaplasia, the latter showing differentiation of the superficial half of the epithelium Figure 5 shows the downgrowth into the glands, which in places

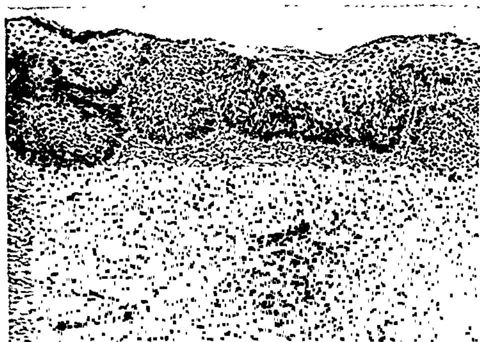


FIG 4 —A small area of definite carcinoma in situ with anaplasia on either side (S-49-1706) Preoperative biopsies showed only anaplasia. The Papanicolaou smear was positive

suggests early stromal invasion. Although this case was treated correctly, it is an excellent demonstration that one must know where to find carcinoma in situ in order to perform accurate cervical biopsies *Carcinoma in situ of the cervix begins at the junction of the columnar and squamous epithelia, and a biopsy which contains only one type of epithelium is not an accurate biopsy* This case also demonstrates the importance of further study should the first biopsy show only anaplasia because carcinoma in situ may be present elsewhere in that cervix

One hundred and fifteen out of 135 cases of carcinoma in situ recently reported from the Free Hospital for Women were similar to those pictured in Figs 1, 4, and 5. In 50 per cent of these cases the malignant epithelium was confined entirely to the surface and was not growing down into the cervical glands (*surface*

on radium therapy. Radium is seldom if ever indicated as the treatment for carcinoma in situ of the cervix.

Figure 7 shows the biopsy specimen taken from a cervix in 1936. Eight pathologists agreed with the diagnosis of definite carcinoma in situ, one regarded it as precancerous, and the tenth made the diagnosis of "nonmalignant reparative process." The patient's cervix was cauterized at the time of the original biopsy in 1936. Thirteen and one half years later her cervix is normal clinically, the Schiller test is negative, and tissue curetted from the endocervical canal and removed from the portio of the cervix is normal microscopically. During the past four years annual Papanicolaou smears have been negative. *This patient and 22 others all showing definite carcinoma in situ have been followed from three to 14 years and apparently have been cured, in most cases unwittingly, by cauterization of the cervix.* Six others were cured also as demonstrated by negative serial block study of the excised cervix one month to six years later.



Fig. 7.—Biopsy specimen taken in 1936 at the time of thorough cauterization of the cervix from a 33 year old mother of 6 children undergoing a repair of the perineum. The section shows typical carcinoma in situ. On the right of the photomicrograph there is glandular involvement and beyond there is questionable stromal invasion (Path. No. 26609). The patient has had no further treatment and all tests and examinations are negative 13½ years later.

Fourteen patients who for the most part have had carcinoma in situ with glandular involvement were not cured by cauterization of the cervix, but the delay in treatment did not jeopardize the eventual outcome because all have been cured by subsequent hysterectomy one to 14 months after the original biopsy. There has been no recurrence of the disease following more radical treatment in one of these patients although a hysterectomy was not performed in some cases up to 14 months after the disease was first recognized.

upper third of the vagina, but in these cases, Gram's iodine solution failed to stain the diseased epithelium.

The distinction between *surface involvement only* and *glandular involvement* is of considerable practical importance. The former is the earlier stage of carcinoma in situ, and at least 85 per cent of these cases can be cured by thorough cauterization or conization The cases in which repeated biopsies show glandular involvement and there is no surface differentiation must be treated by hysterectomy. If serial block sections of an amputated cervix show complete removal of an unsuspected carcinoma in situ, that patient in all probability will be cured



Fig 6—Surface biopsy from a symptomless nulliparous single woman of 50 with a positive vaginal smear and
This photomicrogra
indicate more exte
showed that all of
operative evaluatior
lymph nodes were negative

of that cancer In cases with glandular involvement, however, the disease is so obviously malignant that nothing short of a complete hysterectomy should ever be considered Doing no more than amputation when there is glandular involvement is justifiable only in cases of cervical amputation as part of a Manchester operation in which the disease was not suspected preoperatively and in which serial block sections show complete removal of the lesion Such a case must be followed by curettage of the remaining cervical canal and Papanicolaou smears It would be much safer, however, to remove the remainder of the uterus if there is any suspicion that the lesion was not removed completely rather than to rely



FIG. 8.—An equivocal carcinoma in situ because of surface differentiation. The entire lesion is in this photomicrograph showing the origin of squamous cell neoplasia at the junction of the glandular epithelium. Quite characteristically the malignant epithelium peeled off the underlying stroma, while the normal squamous epithelium remained attached (S-17-1013). The patient has had no treatment, has had her third child, and two years later biopsies and vaginal smears are negative.

A 24 year old nulliparous patient, whose cervix had been cauterized one year previously for a congenital erosion, came to the clinic because of persistent leukorrhea. Inspection of her cervix showed a "spotty erosion" suggesting inadequate cauterization The Schiller test showed a number of small nonstaining areas The vaginal smear was positive, and the biopsy showed carcinoma in situ without gland involvement. Three sets of multiple biopsies during the next eight months showed that the disease persisted but remained as a surface lesion. No gland involvement could be demonstrated, and endocervical curettage showed no extension of the surface malignancy into the cervical canal. During this time vaginal and cervical smears were consistently positive Nine months after the first positive biopsy a superficial but wide conization was performed by knife dissection. Serial block sections showed numerous scattered areas of carcinoma in situ which did not involve the glands. Since then (one year) biopsies, vaginal smears, the Schiller test, and endocervical curettings have been negative. The patient has been told she is cured and may try to become pregnant. Obviously, however, she will be followed most carefully

As the result of routine biopsy of all cervical lesions there has been an increase in the number of disturbing variations observed in the squamous and metaplastic epithelia of that organ. All gradations from normal to definite carcinoma in situ with early stromal invasion can be found in one cervix (Figs 4 and 5). This teaches us the possible significance of the disturbing microscopic picture seen in some cervices which come under the classification of anaplasia. Under the term anaplasia we include the cervices showing basal hyperactivity and the equivocal carcinomas in situ (possible, questionable, and probable carcinoma in situ). Histologically they are characterized by undifferentiated, pleomorphic, hyperchromatic cells replacing the lower half or more of the squamous epithelial layer The more nearly it approaches the surface and the more undifferentiated it is, the more nearly it approaches definite carcinoma in situ When the first biopsy of the cervix shows anaplasia, repeat biopsies must be performed because carcinoma in situ or even early invasive cancer may be present elsewhere in that cervix. At least 15 cases have been observed in the past five years in which the first cervical biopsy showed anaplasia, and by subsequent study during the course of the following three to 12 months carcinoma in situ has been found. At the present time all cases showing anaplasia of the cervix on the first set of biopsies are followed at one to three month intervals by repeat biopsies and vaginal smears until these tests reveal definite carcinoma in situ or all of the tests become consistently negative.

Figure 8 shows the original biopsy from the cervix of a 26 year old mother of 2 children. This biopsy specimen is an excellent example of a probable carcinoma in situ obtained from the anterior lip of the cervix in a positive Schiller test area. There is definite but minimal surface differentiation which places it in the equivocal group. Yet, positive Papanicolaou smears were obtained from this patient. Subsequent biopsies during the next six months showed lesser degrees of anaplasia, and then the patient became pregnant. Two years after the first probably positive biopsy and definitely positive Papanicolaou smears this patient's cervix appears normal clinically, and biopsies, and vaginal smears are now negative. The cervix was not treated except for multiple punch biopsies, and pregnancy did not influence the condition. This case represents the type of anaplasia

stained with a third applicator saturated with Gram's iodine solution. The best applicator is a metal one with the cotton at the end forming a soft, fluffy mass 2 cm. in diameter by 4 to 5 cm. in length. The normal epithelium stains a dark brown within 30 seconds and 45 to 60 seconds is the maximal time required for cleansing and staining.

The contours or distribution of the glandular or metaplastic areas should be noted carefully before the staining is done because *the only useful information from the test is the squamous epithelium which fails to take the stain.* In cases of early squamous cell carcinoma in situ of the cervix the most common finding is a narrow margin of nonstaining epithelium, frequently well localized at the periphery of the erosion or eversion. It may be at the outermost portion of the cervix if there is a wide erosion or inside the external os if the cervix is one which is considered normal on first inspection.

Fortunately most of the carcinomas in situ do involve a part of what appears to be normal squamous epithelium of the portio vaginalis of the cervix. In these cases Schiller's test, carefully performed and interpreted, should arouse the suspicion of the possibility of early malignancy in the nonstaining epithelium at its junction with the glandular epithelium. Such a cervix usually appears as a simple erosion or laceration with exposure of the glandular tissue, and it is not considered at all suspicious according to the older and now out-of-date criteria for gross evidence of malignancy. Occasionally there is a narrow margin of slightly thickened white or paler squamous epithelium at the junction of the two epithelia. From our experience to date the Schiller test is positive in approximately 90 per cent of the cases of this early type of cervical malignancy. Less frequently (about 10 per cent) the malignant surface epithelium is confined entirely to the erosion or eversion, and the Schiller test will be negative. There is no clinical test which will reveal such areas of carcinoma in situ other than the Papanicolaou smear or routine random biopsies around the clock. Unfortunately the Schiller test is of no help in such cases *Carcinoma in situ should be suspected in all erosions and eversions regardless of size, and at least a Papanicolaou smear should be done before treating such a lesion.* At the Free Hospital for Women for a period of over 10 years routine biopsies of benign appearing cervical lesions have produced 1 case of carcinoma in situ for every 100 cases biopsied.

The Papanicolaou smear is nearly as accurate as a carefully performed cervical biopsy when there is carcinoma [illegible] are frequently small, *the select*[illegible] *tance.* A Papanicolaou smear p[illegible] biopsy is not done with the help of the Schiller test. When possible, both methods should be employed before treating a cervix, and biopsies should always be done to confirm a positive smear.

When carcinoma in situ is in its earlier stages, that is, surface involvement only, the Papanicolaou smears are positive in only 71 per cent as compared to 89 per cent in the cases with extension into the glands We can depend, therefore, on the Papanicolaou smear for the more advanced cases of carcinoma in situ of the cervix. *Selective biopsy of all lesions of the cervix, with the aid of the Schiller test plus a Papanicolaou smear, is the ideal routine for the early diagnosis of this symptomless early stage of cervical cancer* During a 21 month period ending

which may be cured by biopsy or may regress spontaneously. Other cases with a similar microscopic picture have been found later to have definite carcinoma in situ

Another patient, aged 26, the mother of 4 children, was being followed because of *anaplasia* of the cervix The original vaginal smear was negative. She returned to the clinic for the third set of biopsies when she was two months pregnant. The Papanicolaou smear then was positive, and the biopsy showed carcinoma in situ with slight surface differentiation In other words, it was a probable or equivocal carcinoma in situ. Through the fifth month of pregnancy the vaginal smears remained definitely positive for cancer, but her cervix showed no gross changes After the fifth month the vaginal smears became negative, and she was delivered normally at term. Postpartum biopsies and smears were negative, and since then she has had her sixth normal pregnancy and delivery. At the present time, which is three years after the positive biopsy and definitely positive vaginal smears, all tests are negative, and the patient's cervix is normal clinically. In this case it should be noted that the vaginal smears remained positive for three months following the positive biopsy so in this instance the regression of the anaplastic lesion must have occurred spontaneously and during pregnancy.

Since advanced cancer of the cervix is seen occasionally in patients in their early 20's and 17 per cent of the cases of carcinoma in situ of the cervix reported by the Free Hospital for Women were in women between 20 and 29 years of age, *we must learn to suspect the early stages of the disease in any cervical lesion at any age.* The youngest patient we are following at the present time is only 16 Yet, she has anaplasia by biopsy and positive vaginal smears

Data are being accumulated which suggest strongly that the long-standing, chronic inflammation and epithelial unrest which exist at the periphery of the so-called congenital erosion are possible etiologic factors in the development of cervical cancer Eight out of 15 nulliparous women with carcinoma in situ had a truly congenital erosion, and many of the remaining 120 cases had what could have been such erosions aggravated by lacerations A lacerated, everted cervix is not unlike an erosion in that the glandular endocervical epithelium is exposed to the vaginal environment and becomes chronically inflamed *All of the small, unequivocal carcinomas in situ have been found at the junction of the two cervical epithelia so nc*

of the portio

junction of t... [illegible]

spreads slowly in all directions on the surface. Later it replaces the columnar cells in the glands As it replaces the squamous epithelium in its peripheral growth there is no visible change, but it is here that the Schiller test is of inestimable value The technic of the Schiller test is so simple, yet its application and interpretation are so frequently misunderstood First, it must be emphasized that it is applicable only to squamous epithelium and not to the glandular or metaplastic epithelium of the erosion or eversion. The cervix is exposed with a bivalve specu-

[illegible]

mucus-dissolving solution such as *Alkolol,* dried with a second applicator, and then

time interval between preinvasive and invasive cancer must be extremely variable, depending on the intensity of the causative factor. We do know from experience and carefully followed patients that anaplasia can exist for two years and carcinoma in situ for up to 14 months without progress. These facts were determined by multiple punch biopsies and vaginal smears, and in each case the experiment terminated with complete section of the excised cervix (hysterectomy).

Figure 9 is from a cervical biopsy performed in May 1948. The patient was then 24 years of age, and she had had definitely positive vaginal smears (Papanicolaou No. 5) for exactly two years. During that interval she became pregnant and was delivered normally of her second child. Fourteen months later the first biopsy was performed and interpreted as definite carcinoma in situ with gland involvement and questionable stromal invasion. A complete hysterectomy was performed with disappointing findings in that minimal anaplasia was the only abnormality present. On reviewing the three sets of preoperative biopsies, recently, it was obvious to us that there was surface differentiation in all and not enough anaplasia to place this lesion in the irreversible group of definite carcinomas in situ. We feel confident that adequate cauterization either with the actual cautery or by electrocoagulation would have been sufficient treatment for this case. Yet, the exfoliated cells in six vaginal and cervical smears were characteristic of cancer for a period of 26 months before hysterectomy.

Figure 10 shows the biopsy from the cervix of a 26 year old mother of a three year old child treated by cauterization in 1947. The section shows marked anaplasia with mitoses at the surface. Yet, there is some surface differentiation. It was interpreted as carcinoma in situ by Dr. Arthur T. Hertig, and one vaginal smear taken six weeks after the cauterization was read as positive by Mrs. Ruth Graham at the Massachusetts General Hospital. Since then, however, all smears and biopsies have been negative, the patient has had her second child, and her cervix is normal.

TREATMENT

These cases are presented not as isolated instances of spontaneous regression or successful conservative treatment but as representative of a large group of cases being observed and followed at the present time. They clearly demonstrate that anaplasia and equivocal carcinoma in situ, even though having positive vaginal smears (Papanicolaou Nos. 4 and 5), may be a reversible process and that it is safe and reasonable to attempt conservative treatment if the patient's co-operation can be obtained. Multiple punch biopsies when performed with the aid of the Schiller test and endocervical curettage are office or clinic procedures which have proved themselves accurate in evaluating the extent of these early malignant lesions. *The accurate appraisal of the extent of the disease, that is, whether the lesion involves just the surface or is growing into glands, and whether it is anaplasia or definite carcinoma in situ, determines the type of treatment for each individual case.* Conservative treatment, cauterization or conization, may be performed safely in cases of anaplasia or even definite carcinoma in situ if no gland involvement is found on at least eight punch biopsies "around the clock" and if tissue from the cervical canal is normal. It is of utmost importance, however, that such conservatively treated patients be

October 1, 1949, 37 cases of carcinoma in situ of the cervix were studied. The first clue to the possible presence of malignancy was obtained by selective cervical biopsy in 21 patients, by vaginal smear in 12, and the disease was found incidentally after hysterectomy for some other reason in 4 The diagnosis of carcinoma in situ was confirmed by biopsy in 9 of the 12 cases found primarily by vaginal smears. In one the biopsy showed marked anaplasia which, plus a definitely positive Papanicolaou smear, prompted the surgeon to remove the uterus in a 48 year old patient. The excised cervix (Figs 4 and 5) showed that the hysterectomy was justified and was adequate treatment A hysterectomy was performed on the remaining 2 patients without any attempt to confirm the positive smears. *This is a practice which should be severely condemned.* Although both cervices were described as not malignant grossly, extensive invasive cancer could have been present for which simple total hysterectomy is not adequate treatment.

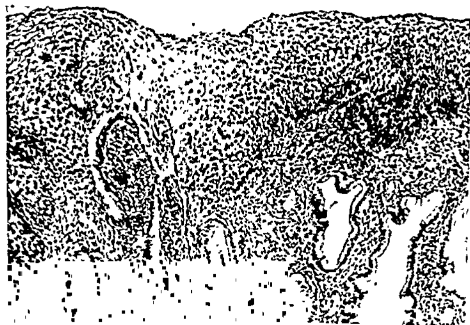


Fig 9 —Second biopsy from a 24 year old patient two years after positive vaginal smear (S-48-1876) During this interval she had her second child Originally this biopsy was interpreted as carcinoma in situ with glandular and questionable stromal involvement, but now it is regarded as equivocal because of the surface differentiation. Six vaginal and cervical smears were positive over a period of 26 months. The hysterectomy specimen showed only anaplasia

The histologic study of cervical epithelia showing basal cell hyperplasia, anaplasia, and carcinoma in situ strongly suggests that squamous cell cancer passes through those phases before it becomes an invasive lesion On the other hand, it would be impossible to state categorically that a single case has been followed and observed to progress from basal hyperplasia to carcinoma in situ because all of these preinvasive phases of malignancy have been seen frequently in the serial sections of one cervix. It is known for a fact that a few cases having anaplasia by biopsy developed invasive cancer within two years Also carcinoma in situ in less than 25 cases has been followed by invasive cancer in from one to 12 years The

informed of the necessity of careful follow-up study by vaginal smears, biopsies, and endocervical curettage. If all of these tests are normal at three month intervals for a year after such treatment, that individual can be regarded as cured, but annual examinations should be strongly urged. *We have had no apparently cured carcinoma in situ recur.* On the other hand, if even anaplasia persists after conservative treatment, a hysterectomy should be performed. *We have had no reason to regret the delay in the ultimate treatment among the unsuccessful conservative attempts to eradicate the early stages of this disease.*

When definite carcinoma in situ is found in one or more biopsies and there is no gland involvement, the biopsies should be repeated to confirm the fact that the disease persists or is no more extensive than originally found. Even then a positive vaginal smear should be obtained after the second biopsy wounds have healed in order to prove that the disease is still present. By following this routine the removal of a negative uterus will be avoided because we have found in some cases by preoperative biopsies that a cure has taken place.

When gland involvement is present, invasive cancer must be ruled out by further evaluation of at least a second set of biopsies including tissue curetted from the cervical canal. If no invasion is found, a simple total hysterectomy should be done, removing the amount of vaginal cuff indicated by the Schiller test. Oophorectomy is performed only if otherwise indicated. Radical hysterectomy with or without removal of lymph nodes is not necessary when there is no invasion.

The facts presented in this discussion are from a personal review of 172 cases of definite carcinoma in situ of the cervix, 75 of which were treated before January 1, 1945, plus over 50 cases of anaplasia of the cervix. There has been only one recurrence among this group of patients treated adequately, but that patient was treated with radium in 1931 after only a *single* biopsy. Four others inadequately treated by trachelorrhaphy before 1932 developed invasive cancer, and 3 of these patients died of the disease.

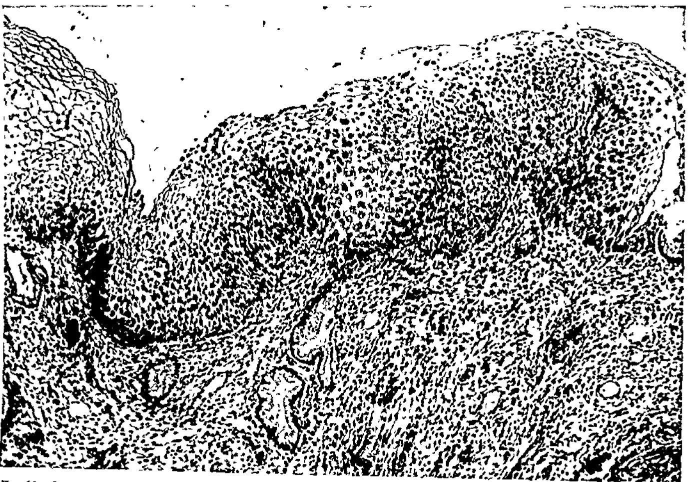


FIG. 10.—Biopsy specimen taken at the time of cauterization of the cervix in a 26 year old unipara with a very small erosion. There are pleomorphism and marked mitotic activity even on the surface, with many atypical mitotic figures in all layers (S-47-1305) The surface differentiation places this case in the equivocal group, although Dr. Arthur T. Hertig originally and on review made the diagnosis of definite carcinoma in situ The patient has since had her second child, and biopsies and Papanicolaou smears are now negative.

the layers so obvious in normal epithelium. There is no evidence of differentiation beyond the basal cell type. Occasionally changes like these are seen in areas where the most superficial cells show normal stratification and differentiation. This is called basal cell hyperactivity and it is often noted in association with cervical cancer. Here again an arbitrary line of classification needs to be drawn and it is both appropriate and convenient to include as carcinoma in situ only those cases where the changes described above extend to the free surface of the epithelium.

In gross appearance, carcinoma in situ is indistinguishable from normal epithelium. The cells, however, have never developed the ability to store glycogen and have no affinity for iodine or other glycogen stains. The Schiller test, of course, utilizes this property to select areas for biopsy. Erosions of the cervix and exposed areas of endocervix also fail to stain with iodine. Although such erosions are often found in association with carcinoma in situ, it is the zone of non-staining, white epithelium at the periphery where biopsy should be taken. This is obvious if one remembers that carcinoma in situ by definition is restricted to the surface layer which is absent in areas of erosion. The relationship between the erosion and the adjacent malignant epithelium is not always clear. In some cases (Younge) of congenital cervical erosion of long standing, paraleukokeratosis and carcinoma in situ have been seen to develop at the border. I believe it is fair to assume that in other cases the erosion represents the effect of slight trauma on an area of epithelium unprotected by normal cornification; that it is, in effect, a direct result of the presence of carcinoma in situ. This may explain the ease with which such erosions can often be made to bleed, and the frequent association of postcoital bleeding with carcinoma in situ. Figure 1 is a low power photomicrograph of a section of the cervix from a patient complaining of postcoital bleeding, in whom a large erosion and carcinoma in situ were found. Note that in the area of erosion one can find no epithelium except for a few deep ends of cervical glands, and that in several of these carcinoma in situ has replaced the normal columnar lining.

Now what of the clinician confronted with the problem of treatment? His decision must be based on the balance of calculated risks; it is essential to him to know the statistical prognosis of a variety of therapeutic alternatives, including, as one of these alternatives, no treatment at all. Younge and his associates have had the opportunity to observe 6 cases of carcinoma in situ which progressed to invasive cancer and his paper cites 12 other instances where this has occurred with sufficient time elapsed between biopsies to suggest that invasive cancer was not present and overlooked at the time of the first examination. At the other end of the scale are a few well authenticated instances where initial biopsy has revealed carcinoma in situ but the cervix has remained healthy for years without further treatment of any sort. Younge points out the possibility that the entire tumor may be destroyed by the biopsy and cites an instance where serial section of the removed uterus found no tumor although biopsy of the cervix a few days earlier was positive In our own series there were 4 instances of this same phenomenon, serial section, however, was not done.

At the Massachusetts General Hospital in all departments, both ward and private, there have been 39 individuals with carcinoma in situ of the cervix

Carcinoma in Situ of the Uterine Cervix

HOWARD ULFELDER, M.D.

PELVIC SURGEONS everywhere are showing great interest in cancer in situ and the reason is not far to seek: it is because they are seeing more of it all the time. This may be due in part to a dissemination of knowledge among pathologists, but a marked increase in the frequency of cervical biopsy is also responsible. It is almost universally recognized now that cancer may lurk in the most innocent appearing cervix and that any open lesion or any area of epithelium that fails to stain with dilute aqueous iodine (the Schiller test) must be studied microscopically. Within the past 10 years the cytologic method of Papanicolaou has also called attention to cases where biopsy should be taken, even though no other indication for such investigation seemed to exist. This particular application of cytology has attracted special attention and recently Pund has pointed out that a specific pattern of exfoliated cells may be found in the presence of carcinoma in situ.

The diagnosis of carcinoma in situ can be made only microscopically.* The epithelium in affected areas shows complete absence of differentiation and other stigmas of abnormal cellular development but without invasion of adjacent tissues. Various observers differ in their interpretation of what constitutes invasion and there is undoubtedly room for argument on the subject. For practical purposes, however, some arbitrary standard should be established to permit collection and classification of material. It would seem wise to set the epithelial basement membrane as the dividing line, and to label "invasive" any lesion where epithelial cells are seen to have penetrated this barrier. Often enough there will be difference of opinion even on this point, and unless every portion of every lesion is studied by serial section, there will be some instances of invasion that never come to light. Within these limitations, however, a real effort should be made to classify accurately each case as it is seen. The squamous epithelium of the exocervix and the columnar epithelium of the endocervix and its glands should be considered one continuous layer with one unbroken basement membrane beneath it. Carcinoma in situ by these criteria will include those cases where lateral replacement of the normal epithelium has occurred, even in the depths of glands, so long as the basement membrane appears intact.

There is general agreement as to what constitutes anaplasia of the epithelium. It is characterized by wide variations in nuclear size and chromatin distribution, by an increase in the number of nuclei and of mitoses and by disappearance of

* Sincere appreciation is expressed to Drs. Robert H Fennell and Tracy B Mallory of the Department of Pathology, Massachusetts General Hospital, for their assistance in the pathologic descriptions, and particularly for their painstaking review of all the sections of tumors investigated in the course of preparation of this paper

treated up to January 1, 1949. Included in this review are all cases in which the microscopic appearance at present conforms to the criteria enumerated above. The average age of this group of patients at the time of diagnosis was 46.4 years. Thirty-eight were married, and out of 24 where the age at marriage is recorded, 11 were under 20 years of age. Lombard and Potter have analyzed a group of 519 patients with invasive cancer of the cervix and they point out that by applying a formula to determine those associated factors which can be considered of statistical significance, it can be shown that the age at marriage is one of the few factors that stands the acid test. In their series 45.4 per cent of patients with cancer of the cervix were married by the time they were 20 years of age, as compared with 16 to 19 per cent of women from large control groups. Even in our small series of cases with cancer in situ we find 45.8 per cent who married early, a striking correlation with Lombard's observation and another fact to suggest some close relationship between carcinoma in situ and invasive cancer. The number of cases seen has increased in recent years, but even more interesting are the figures in Table I, where the cases each year have been classified according to the factor considered by this reviewer to have been responsible for the discovery of the lesion. One notes little change in the rate of discovery by symptom, biopsy for suspicion, or as an incidental pathologic observation in cervix or uterus removed for other cause. Of recent years, however, there has been a sizable increment of cases where a doubtful or positive smear was the first hint that the lesion existed

TABLE I

		Detected by			
Year	*No Cases*	*Biopsy*	*Symptoms*	*Routine Pathology*	*Smear*
1939	4		2	2	
1940	1			1	
1941	1	1			
1942	2	1		1	
1943	3	1		2	
1944	4		1	2	1
1945	1				1
1946	1	1			
1947	13	2	1	1	9
1948	9	1		1	7
	39				

Removal of the uterus has been almost standard therapy here. Total hysterectomy has been done in 27 instances and a more radical type of hysterectomy in 10 others. The 2 remaining cases had excision of cervical remnants remaining after supracervical hysterectomy years before. No case is known to have had local recurrence or metastasis, and none died in the hospital Seven have been seen alive and free of disease five or more years after treatment.

This presents the facts about the cases known to have had carcinoma in situ but the clinical picture of this disease is not complete until one knows in addition how often it has been suspected and what has been the subsequent course in patients where the final diagnosis proved to be something else. There have been 7 instances where biopsy revealed *cancer in situ* and therapy has been





A B



C

It may be concluded on the basis of our own experience that this lesion can safely and adequately be managed by taking multiple biopsies of the cervix and endocervix to exclude invasive cancer and then to remove in one piece the cervix, fundus uteri if present, and a circumferential cuff of vagina 1 cm. or more in width. This specimen, particularly its edges, should be examined microscopically to establish that excision is complete before treatment can be considered at an end, for in 2 cases we have found appreciable extension over the vagina adjacent to the cervix. More radical therapy than this may be considered leaning in the direction of overtreatment, and anything less must be accepted by the clinician as justified only at the risk of recurrence. In every case but 3 in this series the lesion involved endocervical glands to a greater or lesser degree. It would seem hazardous to attempt at present to set up subclassifications of carcinoma in situ with the hope of justifying any therapy less than total removal or total destruction.

It is appropriate to point out that carcinoma in situ is of compelling interest also to the experimental pathologist, whose scientific curiosity is stimulated by his urge to understand the natural history of malignant disease. Certainly it is permissible on the basis of the evidence at hand to hypothecate that epithelial cancer starts in the basal layer and progresses through stages indistinguishable from basal hyperactivity, carcinoma in situ, and then to invasion. Indeed, the identical circumstantial evidence put forward by Schiller, to support his thesis that carcinoma in situ was an early manifestation of squamous cancer, can be applied to bolster the contention that basal hyperactivity is an earlier stage of carcinoma in situ. Any definition of cancer that excludes lesions which have not invaded adjacent tissues is inadequate by present concepts. On the other hand, no definition of cancer can avoid the inevitability of future invasion, and to predict behavior on the basis of cellular morphology alone is to be on notoriously treacherous ground. Probably the relatively gross technics for studying cell anatomy can take us no further and future exploration must follow paths which will disclose ultramicroscopic molecular arrangements.

Quite another approach entails the excision of living tissues to permit observations on their behavior over a period of time under test conditions. Many data are accumulating on the chemical anatomy of cells as indicated by their enzyme systems. Correlation between these studies and the clinical course of tumors will inevitably demonstrate some chemical patterns constantly associated with behavior patterns.

Finally one may transplant living tumor tissue into a medium extremely favorable for growth and theoretically free of any local suppressing influences that obtain in its natural environment. One might expect neoplastic behavior to be markedly accelerated under these circumstances, if the malignant potential is present in the transplant

These and many other technics for measuring individual cell characteristics are constantly being applied today in hundreds of scattered laboratories. Eventually orderly minds will synthesize the data and arrange abnormal tissues into a spectrum which progresses from the benign to the malignant, indicating wherever regression is possible and where, if anywhere, the advance becomes irreversible

predicated on this diagnosis, but where the final pathologic report has been "invasive cancer." Six of these are cases where the change in classification is due entirely to our present re-evaluation and all survived treatment and are known to be alive one to eight years later The remaining case is one where all preoperative studies failed to disclose the true nature of the lesion This question of correlation between preoperative biopsies and final diagnosis is of fundamental importance for obvious reasons and it is comforting to note that in other reports and in this one there are so few examples of this error. Even more comforting is the fact that no such case has had recurrence or metastasis. It is interesting in this connection that in a review of invasive cervical cancer by Morris and Meigs one finds 22 instances where simple total hysterectomy was the only treatment in a group of stage I lesions so small that they were unsuspected at the time of operation, but that only 2 of this group had recurrence of their disease at the end of the usual five year period of follow-up



FIG 2 —High power detail of cervical epithelium considered abnormal but not carcinoma in situ The smear was positive.

Fourteen cases originally catalogued as carcinoma in situ have been excluded from this review as failing to meet the minimal standards Three had positive smears. Seven had positive biopsies, and in the other 7 the biopsy raised the question of carcinoma in situ. Excision of the cervical stump, simple or radical hysterectomy was done in every case and the present diagnosis must be accepted as final. Figure 2 presents an area from the sections of one of these patients; it illustrates, better than words can describe, the problem in classification which often confronts us. Another such instance occurred in a patient four months pregnant, but this case also has been excluded and we have no individual in our series with concomitant pregnancy and carcinoma in situ.

predicated on this diagnosis, but where the final pathologic report has been "invasive cancer." Six of these are cases where the change in classification is due entirely to our present re-evaluation and all survived treatment and are known to be alive one to eight years later. The remaining case is one where all preoperative studies failed to disclose the true nature of the lesion. This question of correlation between preoperative biopsies and final diagnosis is of fundamental importance for obvious reasons and it is comforting to note that in other reports and in this one there are so few examples of this error. Even more comforting is the fact that no such case has had recurrence or metastasis. It is interesting in this connection that in a review of invasive cervical cancer by Morris and Meigs one finds 22 instances where simple total hysterectomy was the only treatment in a group of stage I lesions so small that they were unsuspected at the time of operation, but that only 2 of this group had recurrence of their disease at the end of the usual five year period of follow-up.



FIG. 2.—High power detail of cervical epithelium considered abnormal but not carcinoma *in situ* The smear was positive

Fourteen cases originally catalogued as carcinoma in situ have been excluded from this review as failing to meet the minimal standards Three had positive smears. Seven had positive biopsies, and in the other 7 the biopsy raised the question of carcinoma in situ. Excision of the cervical stump, simple or radical hysterectomy was done in every case and the present diagnosis must be accepted as final. Figure 2 presents an area from the sections of one of these patients; it illustrates, better than words can describe, the problem in classification which often confronts us. Another such instance occurred in a patient four months pregnant, but this case also has been excluded and we have no individual in our series with concomitant pregnancy and carcinoma in situ.

It may be concluded on the basis of our own experience that this lesion can safely and adequately be managed by taking multiple biopsies of the cervix and endocervix to exclude invasive cancer and then to remove in one piece the cervix, fundus uteri if present, and a circumferential cuff of vagina 1 cm. or more in width. This specimen, particularly its edges, should be examined microscopically to establish that excision is complete before treatment can be considered at an end, for in 2 cases we have found appreciable extension over the vagina adjacent to the cervix. More radical therapy than this may be considered leaning in the direction of overtreatment, and anything less must be accepted by the clinician as justified only at the risk of recurrence. In every case but 3 in this series the lesion involved endocervical glands to a greater or lesser degree. It would seem hazardous to attempt at present to set up subclassifications of carcinoma in situ with the hope of justifying any therapy less than total removal or total destruction.

It is appropriate to point out that carcinoma in situ is of compelling interest also to the experimental pathologist, whose scientific curiosity is stimulated by his urge to understand the natural history of malignant disease. Certainly it is permissible on the basis of the evidence at hand to hypothecate that epithelial cancer starts in the basal layer and progresses through stages indistinguishable from basal hyperactivity, carcinoma in situ, and then to invasion. Indeed, the identical circumstantial evidence put forward by Schiller, to support his thesis that carcinoma in situ was an early manifestation of squamous cancer, can be applied to bolster the contention that basal hyperactivity is an earlier stage of carcinoma in situ. Any definition of cancer that excludes lesions which have not invaded adjacent tissues is inadequate by present concepts. On the other hand, no definition of cancer can avoid the inevitability of future invasion, and to predict behavior on the basis of cellular morphology alone is to be on notoriously treacherous ground. Probably the relatively gross technics for studying cell anatomy can take us no further and future exploration must follow paths which will disclose ultramicroscopic molecular arrangements.

Quite another approach entails the excision of living tissues to permit observations on their behavior over a period of time under test conditions. Many data are accumulating on the chemical anatomy of cells as indicated by their enzyme systems. Correlation between these studies and the clinical course of tumors will inevitably demonstrate some chemical patterns constantly associated with behavior patterns.

Finally one may transplant living tumor tissue into a medium extremely favorable for growth and theoretically free of any local suppressing influences that obtain in its natural environment. One might expect neoplastic behavior to be markedly accelerated under these circumstances, if the malignant potential is present in the transplant.

These and many other technics for measuring individual cell characteristics are constantly being applied today in hundreds of scattered laboratories. Eventually orderly minds will synthesize the data and arrange abnormal tissues into a spectrum which progresses from the benign to the malignant, indicating wherever regression is possible and where, if anywhere, the advance becomes irreversible.

predicated on this diagnosis, but where the final pathologic report has been "invasive cancer." Six of these are cases where the change in classification is due entirely to our present re-evaluation and all survived treatment and are known to be alive one to eight years later The remaining case is one where all preoperative studies failed to disclose the true nature of the lesion. This question of correlation between preoperative biopsies and final diagnosis is of fundamental importance for obvious reasons and it is comforting to note that in other reports and in this one there are so few examples of this error. Even more comforting is the fact that no such case has had recurrence or metastasis. It is interesting in this connection that in a review of invasive cervical cancer by Morris and Meigs one finds 22 instances where simple total hysterectomy was the only treatment in a group of stage I lesions so small that they were unsuspected at the time of operation, but that only 2 of this group had recurrence of their disease at the end of the usual five year period of follow-up.



FIG 2 —High power detail of cervical epithelium considered abnormal but not carcinoma in situ The smear was positive.

Fourteen cases originally catalogued as carcinoma in situ have been excluded from this review as failing to meet the minimal standards. Three had positive smears. Seven had positive biopsies, and in the other 7 the biopsy raised the question of carcinoma in situ. Excision of the cervical stump, simple or radical hysterectomy was done in every case and the present diagnosis must be accepted as final. Figure 2 presents an area from the sections of one of these patients; it illustrates, better than words can describe, the problem in classification which often confronts us. Another such instance occurred in a patient four months pregnant, but this case also has been excluded and we have no individual in our series with concomitant pregnancy and carcinoma in situ.

biopsies and 117 were discovered in uteri that were removed with preliminary biopsy (Table I).

TABLE I

MATERIAL

Preinvasive Carcinoma	*Number*	*Positive Film*	*Hysterectomy*	*Confirmed Preinvasive*	*Invasive*	*No Remnant*
Cervical and endocervical biopsy U of Georgia	181	83	88	61	5*	22
Cervical and endocervical biopsy, Oliver General Hospital	25	14	9	8	0	1
Uterus without previous biopsy, U of Georgia	117	11				
Totals	320	108	97	69	5*	23
Covert Invasive Carcinoma						
Cervical and endocervical biopsy, U of Georgia	28	19	4		4	
Cervical and endocervical biopsy, Oliver General Hospital	5	2	2		2	
Uterus without previous biopsy, U of Georgia	29					
Totals	62	21	6		6	

* In all 5 specimens the carcinoma was only slightly invasive

During the 10 year period of intensive study, we became interested also in another form of subclinical cancer of the cervix, which we have designated as *covert invasive carcinoma.* The covert invasive carcinoma is one which is concealed from view, because the invasion is limited to the endocervix. The extent of covert invasive carcinoma varied from minute foci of invasion, which were detected only in microscopic sections, to tumefaction of the entire cervix without, however, penetration of the vaginal surface Preinvasive borders were frequently observed microscopically. We, therefore, believe that the covert invasive carcinoma represents a stage in the development of clinical cancer of the cervix and shall include these cases in this presentation. Because invasion frequently begins in the endocervix and because preinvasive borders are commonly observed in invasive carcinomas, we do not believe a diagnosis of preinvasive carcinoma should be made from a biopsy alone. Endocervical curettings should be secured in order to determine the presence or absence of invasion. Covert invasive carcinomas have been diagnosed in 62 patients Twenty-nine of these were observed in uteri which had been removed for conditions other than carcinoma and 33 were diagnosed from a histologic study of biopsies or endocervical curettings.

In the past three and one-half years we have observed an increased number of subclinical cancers because of cytologic studies of endocervical smears. Of the 209 cases of preinvasive carcinoma of the cervix 97 were detected by smears prior to biopsy and an additional 11 preinvasive carcinomas were detected in uteri prior to hysterectomy in which no biopsy was secured. Similarly we have detected 21 cases of covert invasive carcinoma Ninety-seven hysterectomies have been performed because of a previous diagnosis of surface carcinoma from a study of biopsy or endocervical curettings In 74, remains of the carcinoma were present, while in 23 we were unable to confirm the diagnosis by postoperative examination of the uterus However, 8 of these had been subjected to endocervical curettage, in 4 the cervix had been cauterized, radium had been used in

Cancer in Situ (Preinvasive) of the Cervix Uteri

EDGAR R. PUND, M.D., AND JOE M. BLUMBERG, LT. COL., M.C., U.S.A.

THE DIAGNOSIS of surface carcinoma is based on cytologic alterations of normal epithelium with preservation of tissue relationship, functional epithelium is changed into a vegetative type Our own observations have led us to believe that the epithelial cells of this disorder are fully neoplastic and will ultimately invade the underlying stroma unless eradicated. For this reason we consider the term "preinvasive carcinoma" as best descriptive of the disease There are, however, deficiencies in our knowledge of preinvasive carcinoma of the cervix uteri and conclusions cannot be considered factual or final. It is therefore essential that conclusions be drawn from all available material. This is particularly true today, because the presence of a preinvasive carcinoma can be detected by the method of exfoliative cytology and diagnosed by histologic study of a biopsy. If the assumption be correct that preinvasive carcinomas will ultimately result in invasive carcinomas, then adequate therapy before the occurrence of invasion should result in a tremendous increase in the cure rate of cancer of the cervix

MATERIAL

The material for this study was acquired over a period of 10 years of intensive search in the Department of Pathology of the University of Georgia School of Medicine. All digressions from normal of the epithelium of the cervix uteri were carefully appraised, both in biopsies and in uteri Special attention was directed to the squamocolumnar junction because this is the most frequent site of carcinoma For a period of five years serial blocks were studied from the cervix of all uteri which were removed for conditions other than cancer Cytologic studies were begun three and one-half years ago, and, at the present time, endocervical smears have been obtained from approximately 15,000 women. The arduous task of cutting and examining serial blocks from the cervices, two to 10 in number, has been abandoned except in instances when endocervical smears were suspicious of cancer and in cases of pregnancy. When uteri were removed without previous cytologic study or when endocervical smears were negative, a routine block was removed from each lip of the cervix unless otherwise indicated by gross appraisal However, when dissociated intra-epithelial anaplasia was observed in routine sections, serial blocks were studied. Furthermore we have reviewed all cervical biopsies in the files of the University which cover a period of 27 years. For the past two years similar studies have been made at the Oliver General Army Hospital. Preinvasive carcinoma has been diagnosed in 326 patients. In 209, the diagnosis was made from a study of cervical or endocervical

criterion for judgment of the duration of the neoplasm and for urgency in complete eradication by surgical means.

It is difficult, and we believe unwarranted, to attempt to prove definitely that every preinvasive carcinoma will ultimately develop invasive characteristics. Sufficient evidence has accumulated to indicate that this is probable. It would be hazardous, indeed, to observe a patient with preinvasive carcinoma over a period of time until invasion developed. Supportive evidence may come from the development of chemical tests. Because most of the patients in whom the diagnosis of preinvasive carcinoma is made are treated adequately for early carcinoma, we expect in the next few years to collect data from our files which will demonstrate a decline in the incidence of overt invasive carcinoma.



FIG 2.—Preinvasive carcinoma of the junctional endocervix, squamous cell type. Carcinoma found in routine sections from the uterus of a white female, aged 36. The carcinoma extends into several glands, but remains confined to natural surfaces.
(U of Georgia #48941, Armed Forces Inst. of Path., Ac 218551-40)

The reproductive period is the usual time of onset of the early carcinoma; however, the manifestations of clinical cancer may be long delayed. Among the deficiencies in our knowledge is the relationship of pregnancy to cancer. We cannot explain the large number of preinvasive carcinomas that we have observed in pregnant uteri. We have had the opportunity of examining by serial blocks the cervices of 81 pregnant or postpartum uteri. In these we have found 12 preinvasive carcinomas and 1 invasive covert carcinoma and in 6 there were borderline changes Three of the preinvasive carcinomas and the 1 invasive covert carcinoma were detected with cytologic study of endocervical smears and proved by biopsy. Therefore 9 of the 77 uteri without a diagnosis of carcinoma con-

3, and in 1 the cervix had been amputated. In only 5 of the 97 uteri did the cancer prove to be invasive and in all of these invasion was so slight as not to contraindicate operative procedures. In only 1 of these 5 was the endocervix intentionally curetted, in 2, biopsies of the cervix alone were submitted, and in 2 the diagnosis was made from endocervical tissue which was accidentally obtained at the time of corporeal curettage.

THE STATUS OF PREINVASIVE CARCINOMA

We define a preinvasive carcinoma as one in which the neoplastic epithelium remains confined to the natural surfaces and does not penetrate the barrier of the underlying restraining stroma. This carcinoma frequently extends into the glands, apparently in continuity with the surface (Fig. 2). Involvement of the

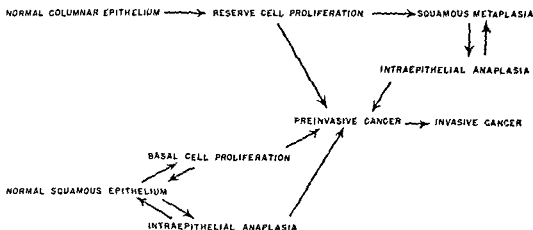
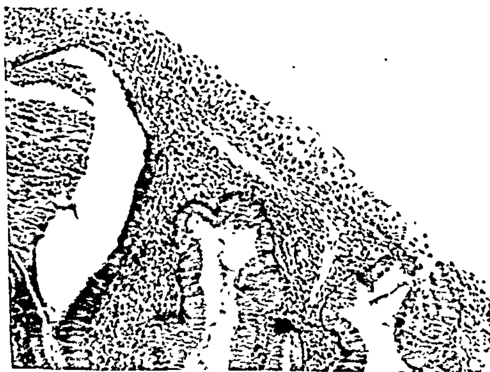


FIG. 1.—Diagram illustrating morphologic changes of the cervical epithelium in relation to carcinogenesis
(*South M. J.*, 43:384, 1950.)

endocervical mucous glands is not considered valid evidence of invasion as long as the growth is confined to the natural surfaces. As the anaplastic epithelium extends into the glands, the normal columnar epithelium is undermined and displaced inward, so that the lumina become narrowed. Careful study will show that the outermost neoplastic cells line the previous natural surface. The distinction between surface spread and invasion is most important because the selection of curative procedures and the extent of surgical treatment depends on the presence or absence of invasion. In most of our cases the involvement of the glands appeared to be a direct extension from the surface, however, on several occasions, it seemed that the cancer arose in many foci, both on the surface and in the glands. From a histologic diagnostic standpoint the extension of the neoplastic cells into the glands proves a fortunate circumstance. Frequently from manipulation in securing a biopsy, much of the surface may be denuded from the specimen but the presence of anaplastic cells in the glands may affirm the diagnosis. Because the period of time between preinvasion and invasion may be reckoned in years, the extent of glandular involvement may be utilized as a



FIG. 4.—Preinvasive carcinoma of the junctional endocervix, imperfectly differentiated squamous cell type. Carcinoma found in routine sections from the uterus of a Negro female, aged 38 (U of Georgia #64736.)



The cells are uniform and the layer
...rs, squamous metaplasia will result.
... with an increase in the layers, preinvasive carcinoma will result. Compare with Figs. 5 and 6 Section from biopsy of cervix of a white female, aged 26.
(U of Georgia #79024.)

tained a preinvasive carcinoma—a rather startling 11.7 per cent. More study is needed to clarify this observation. One would be tempted to deduce that the preinvasive carcinomas may sometimes be reversible Cytologic study seems to indicate that this deduction is probable Six pregnant patients have had positive cervical smears and immediately following delivery, smears became negative and have remained negative for a maximum period of six months.

ORIGIN

The squamocolumnar junction is the most frequent site of carcinoma of the cervix (Fig. 3). This is particularly true of the preinvasive carcinomas (Fig. 4). Even with due allowance for possible fluctuations of the line of this junction in



FIG 3—*Squamocolumnar junction of a normal cervix This is the most frequent site of carcinoma and of squamous metaplasia.*
(U of Georgia #77082, Armed Forces Inst Path Ac 218551-68)

instances of pseudo-erosion and also with due allowance for ectropion in the deeply lacerated specimen, we are impressed with the nearly uniform location of the early lesions Involvement of the stratified squamous epithelial surface occurred in only a relatively small number of our specimens and in most it was usually attributable to a downgrowth and replacement rather than to origin on this surface The vertical extent was surprising, the larger lesions covered as much as 2 cm The lateral (transverse) extent was more limited than the vertical, however, it was occasionally circumferential Evidence that the remote source of most preinvasive cancers is the endocervical basal cell or, better, the reserve cell, is striking. These groups of cells are demonstrable in nearly all human cervices and are capable of noncancerous multiplication to form squamous metaplasia. The location of these cells corresponds to the location of early carcinoma.



FIG. 4.—Preinvasive carcinoma of the junctional endocervix, imperfectly differentiated squamous cell type. Carcinoma found in routine sections from the uterus of a Negro female, aged 38. (U. of Georgia #64736.)



FIG. 5.—Reserve cell hyperplasia of the junctional endocervix. The cells are uniform and the layer is composed of only two to four cells. If differentiation occurs, squamous metaplasia will result. If anaplasia ensues with an increase in the layers, preinvasive carcinoma will result. Compare with Figs. 5 and 6. Section from biopsy of cervix of a white female, aged 26. (U. of Georgia #79024.)

Morphologically these primitive reserve cells and the proliferating cell clusters bear a close resemblance to the common small cell surface neoplasm In fact, the nature of small groups and clusters frequently cannot be determined with certainty (Fig 5). It is only after multiple layers are formed and progressive outward differentiation or continued anaplastic growth becomes apparent that a diagnosis can be established of squamous metaplasia (Fig. 6) on the one hand and preinvasive carcinoma on the other (Fig. 7). We believe that, once started, an autonomous growth can assume any of the microscopic variations observed in the squamous cell carcinomas; therefore, we may see the small hyperchromic spindle cell type which closely resembles its ancestral reserve cell and, in other instances, we may see squamous cell carcinoma, and sometimes there may be an admixture.



Fig. 6 —Squamous metaplasia of the junctional endocervix Note that a number of glands are involved Mature squamous epithelium develops from the reserve cells (Fig 5) A similar involvement may be seen in preinvasive cancer (Fig 2) and should not be considered as invasion. This is not a precancerous lesion
(U of Georgia #45636)

In a previous report we noted that coincident squamous metaplasia of the endocervical epithelium was present in 55 per cent of the cases. This, however, is lower than the expected incidence of 72 per cent as found by us in a previous routine examination of all cervices In a number of cases where metaplasia was absent, the carcinoma was circumferential and extensive. Because the two lesions appear in the same site, we deduce that neoplastic cells have displaced the metaplastic cells in some instances.

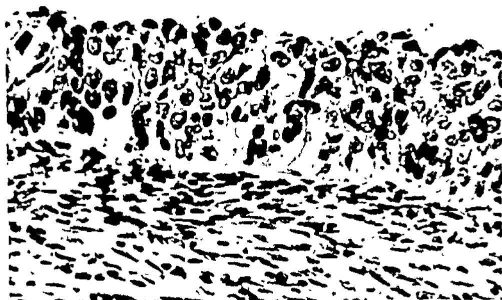


FIG. 7.—Preinvasive carcinoma of the reserve cell type. The cells are anaplastic, pleomorphic, and multilayered, without tendency to differentiate. Compare with Figs. 5 and 6. Circumferential preinvasive carcinoma of the functional endocervix of surface and glands found incidentally in the uterus of a white female, aged 36.
(U. of Georgia #17059, Armed Forces Inst. Path. Ac 218551-47.)



FIG. 8.—Keratinization (leukoplakia) and intra-epithelial anaplasia (dyskaryosis) of portio. This is a borderline change and is frequently continuous with a preinvasive carcinoma which extends into the endocervix. See Fig. 9.
(U. of Georgia #45636.)

Although the majority of preinvasive carcinomas seems to arise from the reserve cells, some preinvasive cancers, however, apparently develop from pre-existing squamous metaplastic epithelium of the junctional endocervix or from [illegible] In these a [illegible] ion of non- [illegible] a transformation of the reversible dissociated intra-epithelial anaplasia (dyskaryosis) into true preinvasive carcinoma which is probably irreversible In cases where much of the vaginal portio was involved, it appeared that the carcinoma arose from a pre-existing leukoplakia with associated dyskaryosis, here the tendency of proliferation is again into the endocervical canal (Figs. 9 and 10). In general, the neoplastic cells seem to displace more readily the columnar or metaplastic squamous cells of the endocervical lining than the normal squamous epithelium.



FIG. 9 —Preinvasive carcinoma of the junctional endocervix which is continuous with a dyskaryotic leukoplakia of the portio Same case as seen in Fig 8
(U of Georgia #45636)

In a similar manner, carcinomas may arise in the junctional endocervix from leukoplakic or keratinizing changes of metaplastic squamous epithelium. The occurrence of keratinizing epithelium (epidermal metaplasia) on the vaginal portio of the cervix and in the metaplastic epithelium of the junctional endocervix should be considered a borderline or precancerous change, provided that there is no prolapse of the cervix This change frequently occurs on the vaginal portio of the prolapsed cervix, however, here it serves a useful purpose. Because of the change of environment of the cervix, it offers more protection than the normal mucous type of epithelium Inasmuch as this is a purposeful transformation, it is

our experience, with others, that carcinomas seldom arise on cervices which have been completely prolapsed. In the absence of prolapse epidermal metaplasia is an atypical change, purely without purpose, therefore entirely an abnormal form of proliferation and one to be considered a borderline or precancerous lesion. The basal cells of the stratum germinativum of pre-existing squamous cells and of metaplastic squamous cells, on occasion, particularly in pregnancy, show a high degree of proliferation. This change we consider a reversible one and occasionally dyskaryosis develops at these sites and preinvasive cancer follows.



FIG 10.—Dyskaryosis of metaplastic squamous epithelium of the junctional endocervix. This change is frequently seen in pregnancy, both on the vaginal portio and in the endocervix. It is probably reversible. Because of its frequent association with preinvasive cancer, it should be considered a borderline change. Section from a pregnant uterus (embryo 4 cm.) from a Negro female, aged 21.
(U. of Georgia #70879.)

BORDERLINE CHANGES

A limited degree of dyskaryosis is commonly observed in papillomas of the cervix as well as of the vagina. Similar changes are also observed in the so-called venereal warts which are presumed to be of virus origin. It would therefore appear that the papillomas of the cervix are also of virus origin. These are frequently noted in pregnancy and have a tendency to disappear spontaneously, although they may persist but will respond to treatment. Our experience in general surgical pathology has led us to believe that venereal warts if not adequately treated may become true invasive cancers. In a similar manner we believe that papillomas of the cervix with pronounced dyskaryosis should be considered precancerous lesions. By precancerous we mean a lesion which does not have

Although the majority of preinvasive carcinomas seems to arise from the reserve cells, some preinvasive cancers, however, apparently develop from pre-existing squamous metaplastic epithelium of the junctional endocervix or from the squamous cell of the vaginal portion of the cervix (Fig. 8) In these a

ion of non-

a transformation of the reversible dissociated intra-epithelial anaplasia (dyskaryosis) into true preinvasive carcinoma which is probably irreversible. In cases where much of the vaginal portio was involved, it appeared that the carcinoma arose from a pre-existing leukoplakia with associated dyskaryosis; here the tendency of proliferation is again into the endocervical canal (Figs. 9 and 10) In general, the neoplastic cells seem to displace more readily the columnar or metaplastic squamous cells of the endocervical lining than the normal squamous epithelium.



Fig 9—Preinvasive carcinoma of the junctional endocervix which is continuous with a dyskaryotic leukoplakia of the portio Same case as seen in Fig. 8
(U of Georgia #45636)

In a similar manner, carcinomas may arise in the junctional endocervix from leukoplakic or keratinizing changes of metaplastic squamous epithelium. The occurrence of keratinizing epithelium (epidermal metaplasia) on the vaginal portio of the cervix and in the metaplastic epithelium of the junctional endocervix should be considered a borderline or precancerous change, provided that there is no prolapse of the cervix This change frequently occurs on the vaginal portio of the prolapsed cervix; however, here it serves a useful purpose. Because of the change of environment of the cervix, it offers more protection than the normal mucous type of epithelium Inasmuch as this is a purposeful transformation, it is

changes may be present in other portions of the cervix and therefore use the term "borderline."

It is unfortunate that cells which are exfoliated from areas of dyskaryosis cannot always be differentiated from cancer cells when examined by the film technic of Papanicolaou. It is difficult, therefore, to follow these patients with



FIG 12.–Early invasive carcinoma of the reserve cell type (covert). Circumferential carcinoma of the junctional endocervix with an occasional focus of superficial invasion found incidentally in the uterus. This is not extension into glands, the neoplastic epithelium has invaded the stroma. (U. of Georgia # 11606, Armed Forces Inst Path Ac 218551-36.)

routine cytologic studies without the use of some type of therapy. At the present time, if there is no definite cancer present, we recommend following the pregnant cases with cytologic studies and have observed that films from a few patients became negative after delivery. If there is no pregnancy and an adequate study of the cervix has eliminated the presence of cancer, we recommend cautery conization of the cervix and then a follow-up with exfoliative cytologic study.

EVIDENCE FAVORING NEOPLASIA

Cytology

The cells that comprise the surface cancers possess the same cytologic characteristics as those of invasive carcinomas. The nuclei are hyperchromatic and vesicular, the nuclear-cytoplasmic ratio is increased; anisokaryosis as well as dyskaryosis is a prominent feature; and there is a tendency to basophilism of the cytoplasm. Polarity of the cells may be completely lost or when differentiation is present it is imperfect and incomplete. The transition of the vegetative cells to differentiation is abrupt. Therefore carcinomas may be of reserve cell type

sufficient characteristic changes to be denoted definitely as cancer but which, through experience, has been shown in a certain number of cases, but not in all, to develop into cancer at a later date.

It is not uncommon to find lesions on the vaginal surface of the cervix near the portio which exhibit a certain amount of intra-epithelial anaplasia similar to that seen in papillomas but without papilloma formation. Moreover, when squamous metaplasia is present in the endocervical canal at the junction, dyskaryosis may occasionally be seen (Fig. 11) Dyskaryosis of normal and metaplastic squamous epithelium and basilar hyperplasia are especially common in cases of pregnancy By basal cell hyperplasia we mean the proliferation of the basal cells of the



Fig 11 —Basilar hyperplasia with slight dyskaryosis in a section of a biopsy from a pregnant (three months) white female, aged 23 This is probably reversible but should be considered a borderline change
(U of Georgia #0-2479)

stratum germinativum in excess of that usually found in the normal squamous epithelium of the portio or of the metaplastic squamous epithelium (Fig. 12) The nuclei are regular and orderly, and these cells show a tendency to differentiate fully into glycogen-containing cells on the surface. While it is possible that this change may be the forerunner of cancer, we do not believe that it has the significance of the intra-epithelial anaplasia.

It is not uncommon to find in serial blocks of cervices a series of gradations such as basilar hyperplasia, dyskaryosis, and preinvasive carcinoma (Figs. 9 and 10) The frequent association of dyskaryosis and basilar proliferation of the normal and metaplastic squamous epithelium with pregnancy suggests that these changes are reversible. Because of a similar association, however, with preinvasive cancer, we must use a term which displays our ignorance as to what

been recognized. Younge, Hertig, and Armstrong have recently reported 18 cases and Ayre and Ayre an additional 1, thus 19 instances have been reported where invasion followed a surface carcinoma. We have also been able to collect 66 cases from the literature of preinvasive carcinoma followed over a period of one to 16 years which have not developed invasive carcinoma. In these 66, however, 60 had received adequate therapy, such as radium, cauterization, hysterectomy, or amputation of the cervix. In 4, trachelorrhaphy had been performed and they had been followed from 10 to 16 years. It is possible that the carcinoma was completely removed by the reparative operation on the cervix. The period of observation of 1 case, which was diagnosed by curettage, and an additional case which was diagnosed in several biopsies, was four and six years, respectively. Another patient in whom amputation of the cervix was performed had been followed for five years and preinvasive carcinoma still persisted. We have recently observed a patient in whom the diagnosis of preinvasive carcinoma was made nine years previously. At a subsequent biopsy this year, preinvasive carcinoma was still present in the cervix.

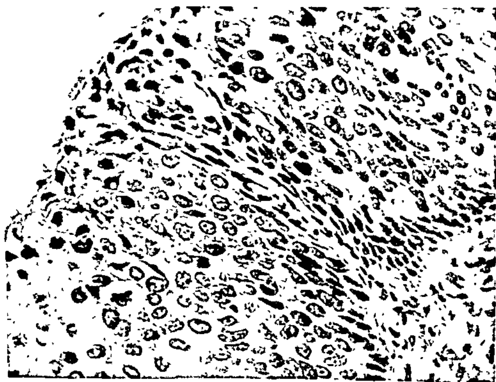


FIG 13.—Preinvasive carcinoma, squamous cell type, of the junctional endocervix from a section of a biopsy from a white female, aged 38. Biopsy was secured and the endocervix was curetted because of a positive cytologic smear. See Fig. 14.

Early invasive carcinomas are frequently bordered by noninvasive epithelial involvement, and, when both preinvasive and invasive areas are demonstrable, the extent of the preinvasive border varies inversely with the amount of invasion. In other words, invasion may begin at one site and gradually destroy the entire preinvasive area. It appears then that the cancerous epithelium springs from the junctional area from an initial focus, or possibly foci, and the growing cells

(Fig. 7) or of squamous cell type (Figs. 2 and 5). Both types with their intermediate gradations may arise from the reserve cells of the columnar epithelium of the junctional endocervix. However the carcinomas which arise from basilar proliferation and dyskaryosis of pre-existing squamous epithelium tend to produce squamous cell carcinomas only (Fig. 10).

Site

Almost all observers agree that the most frequent site of cancer of the uterine cervix is the squamocolumnar junction (Fig. 3). This, too, is the prevailing site for preinvasive carcinoma. The junction of two types of epithelium is a favorable site for the development of cancers in other portions of the body. There exist at this area cells which are capable of replacing the two kinds of epithelium in order to maintain pre-existing relationships. The reserve cells of the junctional endocervix serve this purpose, and, therefore, are probably more responsive to growth stimuli than the maturating cells This explains the frequency of cancer at this site and the predominance of reserve cell type of cancers, especially in the initial stage

Incidence

In examining serial blocks from 1,200 uteri which were removed for reasons other than carcinoma, preinvasive carcinoma was found in 3 9 per cent. This figure compares favorably with the incidence of carcinoma of the cervix, approximately 2 5 per cent The higher figure in our series is probably due to the fact that many of these uteri were removed because of disease of the cervix Furthermore, in examination of endocervical smears from 10,000 women with controlled biopsies, in most cases with suspicious smears, a diagnosis of cancer was made in 2 5 per cent, 1 5 per cent were invasive cancers and 1 per cent were preinvasive.

Age Differential of Preinvasive Carcinoma, Covert Invasive Carcinoma, and Overt Carcinoma

In our first series of cases, which included 47 preinvasive carcinomas and 8 covert invasive carcinomas, there was a difference in the average age of six years, 36 6 years for the preinvasive carcinomas and 42 6 years for the covert invasive carcinomas. One hundred cases of overt invasive carcinomas were selected and the average age of these proved to be 49 years. In this present larger series of preinvasive carcinomas of the uterus, the average age is 37 years, the youngest 19, and the oldest 61. However, the average age of patients with preinvasive carcinoma of the cervix in which the diagnosis was made by biopsy is 40, the youngest being 22 and the oldest 78. The 46 cases of covert invasive carcinoma averages 47 years of age with the youngest 23 and the oldest 76. Based on the average ages of this group of covert invasive carcinomas, it now appears that invasion begins on the average of 10 years after the preinvasive phase and that frank cancer may be delayed an additional two years.

Clinical Course

In a previous article, we were able to collect 14 cases from the literature in which invasion developed from one to 12 years after a preinvasive carcinoma had

been recognized. Younge, Hertig, and Armstrong have recently reported 18 cases and Ayre and Ayre an additional 1; thus 19 instances have been reported where invasion followed a surface carcinoma. We have also been able to collect 66 cases from the literature of preinvasive carcinoma followed over a period of one to 16 years which have not developed invasive carcinoma. In these 66, however, 60 had received adequate therapy, such as radium, cauterization, hysterectomy, or amputation of the cervix. In 4, trachelorrhaphy had been performed and they had been followed from 10 to 16 years. It is possible that the carcinoma was completely removed by the reparative operation on the cervix. The period of observation of 1 case, which was diagnosed by curettage, and an additional case which was diagnosed in several biopsies, was four and six years, respectively. Another patient in whom amputation of the cervix was performed had been followed for five years and preinvasive carcinoma still persisted. We have recently observed a patient in whom the diagnosis of preinvasive carcinoma was made nine years previously. At a subsequent biopsy this year, preinvasive carcinoma was still present in the cervix.

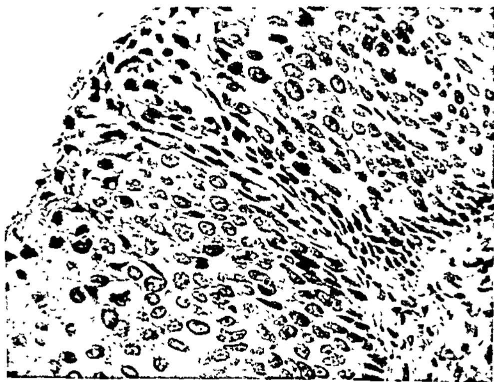


FIG 13 – Preinvasive carcinoma, squamous cell type, of the junctional endocervix from a section of a biopsy from a white female, aged 38. Biopsy was secured and the endocervix was curetted because of a positive cytologic smear. See Fig 14.

Early invasive carcinomas are frequently bordered by noninvasive epithelial involvement, and, when both preinvasive and invasive areas are demonstrable, the extent of the preinvasive border varies inversely with the amount of invasion. In other words, invasion may begin at one site and gradually destroy the entire preinvasive area. It appears then that the cancerous epithelium springs from the junctional area from an initial focus, or possibly foci, and the growing cells

spread vertically and laterally over the endocervical surface and to a less extent onto the squamous surface Furthermore the growing cells extend into the mouths and lumina of the endocervical mucous glands and downward to displace stratified squamous epithelium of the vaginal aspect of the cervix. The neoplastic cells follow normal contours with nicety and are destructive only of pre-existing epithelium in this early phase. After an undetermined period of latency, true invasion of the tissue occurs into the cervical stroma and actual tumefaction begins (Fig. 13). Study of the early invasive phase in our several incidental cases indicates that it usually occurs in a single area, initially, so that the smallest tumors are to one side of the canal or os. It is not unusual, however, for the neoplasm to invade the entire endocervix Even these tumors are often hidden in the intact specimen and are revealed only on section. The early invasive carcinomas are not visible on vaginal examination, and we have therefore denoted them as covert invasive carcinomas. After a shorter period of this phase, the carcinoma breaks through the vaginal portio or involves the portio at the external os and then becomes manifest as a clinical carcinoma

We have stated that the average age of patients with preinvasive carcinoma was 10 years less than that of those with covert invasive carcinoma. However, it should be emphasized that this is an average age interval and the time of invasion in the 14 cases reviewed by us ranged from less than one year to 12 years It would be impossible, on a histologic basis, to determine in individual patients when invasion was likely to occur The extent of glandular involvement and the degree of anaplasia of the neoplastic cells should serve, however, as criteria for urgency of treatment and the extent of surgical procedures.

DETECTION AND DIAGNOSIS OF PREINVASIVE CARCINOMA

We have noted that 81 per cent of patients with preinvasive carcinoma of the cervix are asymptomatic, furthermore, the presence of a preinvasive carcinoma cannot be detected by visualization or palpation. It is true, however, that it may be suspected at sites of epidermal metaplasia and leukoplakia of the everted endocervix and vaginal portio of the cervix From our experience in the handling of 214 uteri as surgical specimens in which preinvasive carcinoma was present, we have never been able to recognize any changes that were characteristic, despite the fact that in 108 of these we knew that a preinvasive carcinoma was present because of a previous cytologic film or biopsy.

For detection, then, of carcinoma in its preinvasive phase, one must rely on the cytologic test devised by Papanicolaou and Traut, which has proved efficacious. In our laboratory we use a method of obtaining material from the endocervical junction by the use of a cotton applicator An ordinary cotton applicator is inserted into the endocervical canal, twirled a few times in one direction and then rolled on a slide In everted cervices the applicator should also be rubbed against the area of eversion. In addition, a film is made from the vaginal pool in order to detect exfoliated atypical endometrial cells and other cells which reflect hormonal activity. The slides are immersed immediately in a solution of equal parts of ether and 95 per cent ethyl alcohol and should remain in this solution for at least 15 minutes but may remain there for several hours. If the slides are

to be mailed to the laboratory, drying is prevented by the technic recommended by Ayre and Dakin. One or two drops of glycerin should be placed on the film and it is then covered with a clean slide or two filmed slides are placed face to face. The endocervical films are stained by the method of Papanicolaou which affords the greatest transparency and the clearest nuclear detail.

We prefer the swab method of obtaining smears. The junctional endocervix is the usual site of incipient cancer and we assume that more atypical cells would be found here than in smears from the vaginal pool. However vaginal smears should also be obtained because of detection of abnormal endometrial cells and for study of cytologic changes reflecting abnormal hormonal activity. Because confirmation is necessary by biopsy, we prefer that the cervix should not be scraped for fear of risk of denudation. With the swab method cancer cells are not found in large numbers and careful prolonged examination is necessary. Smears should be secured from the endocervix during the luteal phase of the cycle because larger numbers exfoliate at this period.

At the present time we have, in association with Nieburgs, evaluated the comparative exfoliative cytology for the detection of cancer of the cervix uteri in 10,000 patients. In the entire series only 332 had positive films. Of these, 234 have been investigated by biopsy with the result that cancer was observed in 185 (79 per cent); 68 of the 185 confirmed cancers proved to be in the preinvasive stage. In our survey then of 10,000 cases, on a corrected figure 2.5 per cent had cancer, 1.5 per cent were invasive, and 1 per cent in the preinvasive phase.

We have called attention to a specific cell which is observed in smears from cervices with preinvasive carcinoma. The recognition of this specific cell has facilitated greatly the detection of cervical cancer in the incipient phase. The morphology of this cell is extremely diverse and can be distinguished only by comparison. The main distinguishing features of cells from preinvasive cancer are the unusually large size. The abundant cytoplasm generally stains a typical yellow-orange color with the Papanicolaou stain. The nuclei may be either small, hyperchromatic with lack of detail and irregular nuclear membrane, or they may be large, foamy, and agranular with well or ill defined borders. Conversely there may be nuclei with distinct borders and a particular type of granularity, unlike that found in invasive carcinoma. In addition there is usually a striking predominance of normal cells and the cells of the vaginal smear may be of the cornified type, although the patient may be in the secretory phase of the cycle or of menopausal age. These cells were found in 71 patients who were investigated by biopsy and 57 of these proved to have preinvasive carcinoma, 4 had invasive cancer, 1 endometrial cancer, in 3 there were borderline changes, and in 6 biopsies were negative. The recognition of this cell, which possesses some attributes of differentiation, is important in following patients in whom surgical interference is either contraindicated or undesirable because of pregnancy, youth, or sterility. A change in the cytology of the smear to one which contains cells of a more anaplastic type may be an indication for more intensive study by biopsy or surgical eradication.

It is generally conceded that the Papanicolaou cytologic method for detection of cancer has passed the experimental stage and is an accepted procedure. It has proved equally efficacious in the detection of preinvasive carcinoma and invasive

spread vertically and laterally over the endocervical surface and to a less extent onto the squamous surface. Furthermore the growing cells extend into the mouths and lumina of the endocervical mucous glands and downward to displace stratified squamous epithelium of the vaginal aspect of the cervix. The neoplastic cells follow normal contours with nicety and are destructive only of pre-existing epithelium in this early phase After an undetermined period of latency, true invasion of the tissue occurs into the cervical stroma and actual tumefaction begins (Fig. 13). Study of the early invasive phase in our several incidental cases indicates that it usually occurs in a single area, initially, so that the smallest tumors are to one side of the canal or os. It is not unusual, however, for the neoplasm to invade the *entire* endocervix. Even these tumors are often hidden in the intact specimen and are revealed only on section. The early invasive carcinomas are not visible on vaginal examination, and we have therefore denoted them as covert invasive carcinomas After a shorter period of this phase, the carcinoma breaks through the vaginal portio or involves the portio at the external os and then becomes manifest as a clinical carcinoma.

We have stated that the average age of patients with preinvasive carcinoma was 10 years less than that of those with covert invasive carcinoma. However, it should be emphasized that this is an average age interval and the time of invasion in the 14 cases reviewed by us ranged from less than one year to 12 years. It would be impossible, on a histologic basis, to determine in individual patients when invasion was likely to occur. The extent of glandular involvement and the degree of anaplasia of the neoplastic cells should serve, however, as criteria for urgency of treatment and the extent of surgical procedures.

DETECTION AND DIAGNOSIS OF PREINVASIVE CARCINOMA

We have noted that 81 per cent of patients with preinvasive carcinoma of the cervix are asymptomatic, furthermore, the presence of a preinvasive carcinoma cannot be detected by visualization or palpation. It is true, however, that it may be suspected at sites of epidermal metaplasia and leukoplakia of the everted endocervix and vaginal portio of the cervix. From our experience in the handling of 214 uteri as surgical specimens in which preinvasive carcinoma was present. we have never been able to recognize any changes that were characteristic, despite the fact that in 108 of these we knew that a preinvasive carcinoma was present because of a previous cytologic film or biopsy.

For detection, then, of carcinoma in its preinvasive phase, one must rely on the cytologic test devised by Papanicolaou and Traut, which has proved efficacious. In our laboratory we use a method of obtaining material from the endocervical junction by the use of a cotton applicator. An ordinary cotton applicator is inserted into the endocervical canal, twirled a few times in one direction and then rolled on a slide In everted cervices the applicator should also be rubbed against the area of eversion. In addition, a film is made from the vaginal pool in order to detect exfoliated atypical endometrial cells and other cells which reflect hormonal activity The slides are immersed immediately in a solution of equal parts of ether and 95 per cent ethyl alcohol and should remain in this solution for at least 15 minutes but may remain there for several hours. If the slides are

commonly begins in the endocervical canal, it enables one to differentiate between a preinvasive and an invasive carcinoma (Fig. 14).

We have noted that covert invasive carcinomas frequently have preinvasive borders. The biopsy may be obtained at the site of the preinvasive border and thus the invasive carcinoma will be missed unless the endocervix is curetted. The value of this procedure has recently been reported by us in a study of 71 cases in which the diagnosis of carcinoma of the cervix was made by examination of biopsies of the cervix or endocervical curettage in which the cancer, in a biopsy, was preinvasive. We have now studied 84 cases by this procedure (Table II). In

TABLE II

BIOPSY AND ENDOCERVICAL CURETTAGE

	Number	Preinvasive Confirmed by Hysterectomy	Invasion Confirmed by Hysterectomy	Failure of Confirmation	No Operation	Error in Invasion
Biopsy preinvasive, scrapings preinvasive	28	17		2	7	2 *
Biopsy preinvasive, scrapings negative	23	9		9	5	
Biopsy negative, scrapings preinvasive	11	4		2	5	
No biopsy, scrapings preinvasive	10	4			5	1 †
Biopsy preinvasive, scrapings invasive	5		2 slight		3	
No biopsy, scrapings invasive	5		2 ‡		3	
Biopsy negative; scrapings negative	2	2				
Total ...	84	36	4	13	28	3

* Only slight invasion Curettings obtained accidentally in 1 case
† Only slight invasion Curettings obtained accidentally
‡ Operation advised in 1 case because of slight invasion Invasion proved superficial in uterus after removal No operation advised in other case because of advanced invasion. Ureter included in specimen

Note "We" in this presentation is editorial in the sense that it refers not only to the contributing authors, but also to our collaborating colleagues of previous publications· S. H. Auerbach, H. E Nieburgs, J B Nettles, Fred Dick, Jr, J E Echols, J. D Caldwell, and E. S Cardwell, Jr. Grateful acknowledgement is made to Miss Juanita Simmans for her recording and collection of data and secretarial assistance

For a more complete bibliography, the reader is referred to the bibliography of the appended articles.

28 cases the biopsy was positive for preinvasive carcinoma and the endocervical curettings were positive for preinvasive carcinoma; 21 of these have been subjected to hysterectomy and in 17 the preinvasive carcinoma was confirmed. In 2 having carcinoma of the uterus a minimal amount of invasion was noted in the specimen obtained from the cervix after hysterectomy. In 23 patients the preinvasive carcinoma was observed in the biopsy of the cervix and no cancer was observed in the endocervical curettings, 18 of these have been subjected to hysterectomy and in 9 the diagnosis was confirmed but in the other 9 no remains of the cancer could be found. Compared with the above series, this is evidence of the smallness of the cancer because much of it was removed by the cervical

carcinoma. However, we believe that confirmation should be sought by biopsies and endocervical curettage because therein lies the definite diagnosis. We consider the examination of cytologic films a method of detection but not one of diagnosis It must be emphasized, however, that multiple biopsies at the squamocolumnar junction are necessary A minimum of four biopsies should be obtained and we have found endocervical curettage a valuable procedure. In this series of 326 cases of preinvasive carcinoma, 108 of the patients were detected by film. During this same period, we have diagnosed 62 covert invasive carcinomas of the cervix, 21 of which were detected by film (Table I).

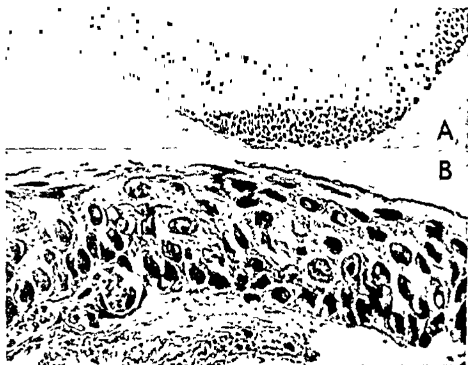


Fig 14 –
in Fig 1
Hysterect
the junctional endocervix in a specimen of uterus from the same patient Remains of carcinoma were found in three of seven blocks of the junctional endocervix
(U of Georgia #82022.)

In patients with an overt invasive carcinoma of the cervix, biopsy alone is all that is necessary to confirm the diagnosis However, when no carcinoma is clinically apparent, preinvasive carcinoma must be differentiated from invasive carcinoma, because, without invasion there is little likelihood of penetration of the lymphatics, and, the possibility of metastasis is remote. The treatment may depend on the absence or presence of invasion, therefore, we recommend in cases with positive films not only multiple biopsies but also endocervical curettage. The endocervical curettage serves two purposes: (1) When the carcinoma is extremely small, it may be missed in the biopsy; thus curettage enables one to make a better survey of the cervix than with biopsy alone. (2) Because invasion so

these cases fell, we deemed it advisable not to use roentgen therapy because of the frequency of complications and its castrating effects. A carcinoma which is confined to the natural surfaces has little opportunity to gain entrance into the lymphatics or blood vessels, and consequently the possibility of metastases is so remote as to be negligible. We therefore recommended total hysterectomy in many of these young women and also suggested that the ovaries be preserved. This surgical procedure removes the entire cancer-bearing area and by preserving the ovaries prevents the sudden onset of menopausal changes. Then, too, if menopausal symptoms do develop at a later date, if the cancer-bearing area has been removed, there will be no contraindication to the use of estrogenic substances for the treatment of the menopausal symptoms.

As our material accumulated and we became cognizant of the fact that invasion may be present in the endocervical canal and not apparent at the site of the biopsy, we advised, as a preliminary to hysterectomy, multiple biopsies of the cervix and endocervical curettage. When the method of exfoliative cytology was introduced and we were able to accumulate a large number of cases both of the preinvasive type and the covert invasive carcinoma, we noted a difference in the age group which had been previously reported on a smaller series of cases. In our first series the average age of the preinvasive cancer patients was 36.6 years, while those who had covert invasive carcinoma the average age was 42 years. It seemed apparent then that, on the average, invasion took place within a period of six years. We hesitated, therefore, to wait before performing hysterectomy on these patients. However, since the cytologic method has enabled us to detect more covert invasive carcinomas, we have noted, with this larger series, that the average age is now 47. It would appear then that the average interval of time for the conversion of a preinvasive carcinoma into an invasive carcinoma is approximately 10 years. We have, therefore, adjusted our recommendations of therapy to this newer knowledge. Furthermore, at the beginning of our studies, the efficacy of the study of cytology had not been determined, especially in reference to preinvasive carcinoma. It is now of proved worth and can be relied on to detect the majority of cancers of the cervix, whether they are preinvasive or invasive.

Our recommendations at the present are as follows: If a cytologic film from the cervix is found to contain cells strongly suggestive of cancer, in other words, a positive Papanicolaou test, we recommend multiple biopsies and endocervical curettage. When this surgical procedure is carried out in the operating room, we further recommend that a cautery conization of the cervix be done at the same time. If study of the biopsy and endocervical curettage gives evidence that the carcinoma is in its preinvasive stage, it is recommended that this patient be followed by cytologic studies to determine if the carcinoma has been eradicated. If a subsequent film proves positive, total hysterectomy is indicated. If invasion is found, the depth and extent of the invasion are determined in so far as possible by the examination of multiple biopsies and endocervical curettage. When invasion appears superficial, an exploration is recommended with hysterectomy as a goal.

We do not now believe that it is necessary to remove the uterus in all cases. We do believe an attempt at eradication of the cancer should be made by cauteriza-

biopsy and by the endocervical curettage, whereas when it was present in the endocervical scrapings, in only 2 of the 19 cases was there a failure to find remains of cancer. In 11 patients the biopsy from the cervix was devoid of any recognizable cancer tissue; however, cancer was found in the endocervical curettage. Six of these have been subjected to hysterectomy and in 4 preinvasive carcinoma was present and in 2 no remains of carcinoma were found. In 10 patients only endocervical scrapings were submitted; 5 of these have been subjected to hysterectomy and preinvasive carcinoma of the uterus was found in 4 and in 1 there was slight invasion. In this 1 case, however, the cervix was not deliberately curetted; the material was included in the corporeal scrapings. In 5 patients the biopsy of the cervix was preinvasive, whereas there was evidence of invasion in the endocervical curettings; in 2 of these the invasion appeared so slight that exploratory laparotomy was recommended with aim of hysterectomy if there was no excessive induration of the cervix, evidence of extension into the paracervical tissues, or absence of evidence of metastases. In both of these patients only slight invasion was present In 5 patients no biopsy was obtained from the cervix but invasive carcinoma was noted in the endocervical curettage. Because of only slight invasion in one, hysterectomy was performed and only slight invasion was present in the cervix of the removed uterus. Advanced invasion was diagnosed in another but, because there was no cancer apparent on the vaginal portion of the cervix, the physician elected hysterectomy and this proved to be an extremely advanced carcinoma which had invaded the paracervical tissues and one ureter was included in the specimen. This patient died shortly of anuria. Two patients had positive cervical smears and an attempt was made to confirm the diagnosis by biopsy and endocervical curettage. In both of these the biopsy was negative and no cancer was found in the scrapings, however preinvasive carcinoma was found in the cervix of the removed uterus. The endocervical scrapings and the biopsy, however, did serve the purpose of ruling out invasive carcinoma.

Our totals then are 82 patients in whom a diagnosis of preinvasive carcinoma was made from the biopsy of the cervix or a diagnosis of carcinoma was made from endocervical curettage alone and 2 patients with negative biopsy and curettings Fifty-six of these have been operated on and in 36 the diagnosis of preinvasive carcinoma was confirmed, in 4 the diagnosis of invasive carcinoma was confirmed, in 13 no remains of carcinoma were observed, and in 3 invasion was found when the previous diagnosis was preinvasive carcinoma. In 2 of these 3 cases, however, the endocervical canal was not deliberately curetted If these 2 cases are eliminated from the 56, then our error in diagnosis with biopsy and scrapings is approximately 5 per cent, but the invasion was so minimal as not to have harmed the patients.

TREATMENT

As pathologists we have frequently been called on to advise as to the proper therapy in cancers of the cervix In the early period of our study, when a diagnosis of preinvasive carcinoma of the cervix was made, the usual procedure was utilized for treating patients with carcinoma, that is—radium which was considered the method of choice Because of the young age group in which many of

Lombard, H. L., and Potter, E. A. Environmental Factors in the Etiology of Cancer. Unpublished Data. (Quoted by Morris and Meigs)

McGraw, J., Personal Communication.

McSweeney, D. J., and McKay, D. G. Uterine Cancer: Its Early Detection by Simple Screening Methods. *New England J. Med.*, 238:867, 1948.

Morris, J. McL., and Meigs, J. V. Carcinoma of the Cervix, Statistical Evaluation of 1,938 Cases and Results of Treatment. *Surg. Gynec. & Obst.*, 90:135, 1950.

Munnell, E. W., and Brunschwig, A. Five Year End Results of Irradiation Therapy of Cancer *of the Cervix Uteri at the Memorial Hospital. Surg., Gynec. & Obst.*, 87:313, 1948.

Nieburgs, H. E., and Pund, E. R. Detection of Cancer of the Cervix Uteri, Evaluation of Comparative Exfoliative Cytologic Diagnosis. A Study of 10,000 Cases. *J.A.M.A.*, *142*:221, 1950.

Nieburgs, H. E., and Pund, E. R. Specific Malignant Cells Exfoliated from Preinvasive Cancer of the Cervix Uteri. *Am. J. Obst. & Gynec.*, 58:532, 1949.

Papanicolaou, G. N., and Traut, H. F. *Diagnosis of Uterine Cancer by Vaginal Smear.* New York. The Commonwealth Fund, 1943.

Pund, E. R., and Auerbach, S. H. Preinvasive Carcinoma of Cervix Uteri. *J.A.M.A.*, *131*:960, 1946.

Pund, E. R., and Echols, J. E. The Value of Endocervical Curettage in the Diagnosis of Preinvasive and Covert Invasive Carcinoma *of the Cervix Uteri. (In press.)*

Pund, E. R., and Nieburgs, H. E. The Detection and Diagnosis of Uterine Cancer. *South. M. J.* (In press.)

Pund, E. R., et al. The Pathology of Early Carcinoma of the Cervix, Status of Preinvasive Cancer, Study of 155 Cases. *South. M. J.*, *41*:711, 1948.

Pund, E. R., et al. Preinvasive and Invasive Carcinoma of the Cervix Uteri, Pathogenesis, Detection, Differential Diagnosis, and Pathologic Basis for Management. *Am. J. Obst. & Gynec.*, 55:831, 1948.

Pund, E. R., et al. Preinvasive Carcinoma of the Cervix Uteri, 7 Cases in Which It Was Detected by Examination of Routine Endocervical Smears. *Arch. Path.*, *44*:571, 1947.

Rubin, I. C. Early Cervical Carcinoma in 3 Clinically Unsuspected Cases Incidental to Plastic Operations. *J. Mt. Sinai Hosp.*, *12*:607, 1945.

Scheffey, L. C. Discussion of Galvin and Te Linde's paper, Present Status of Noninvasive Cervical Carcinoma. *Am. J. Obst. & Gynec.*, 57:32, 1949.

Schiller, W. Clinical Behavior of Early Carcinoma of the Cervix. *Surg., Gynec. & Obst.*, 66:129, 1938.

Schmitz, H., and Benjamin, E. L. Early Histologic Diagnosis of Carcinoma of the Uterine Cervix. *J.A.M.A.*, *103*:808, 1934.

Schram, M., and Di Palma, S. Vaginal and Cervical Smears in Uterine Malignancy. *Am. J. Surg.*, 77:191, 1949.

Skapier, J.: Diagnosis of Preinvasive Carcinoma of the Cervix. *Surg., Gynec. & Obst.*, 66:129, 1938.

Smith, G. V., and Pemberton, F. A. Picture of Very Early Carcinoma of the Uterine Cervix. *Surg., Gynec. & Obst.*, 59:1, 1934.

Stevenson, C. S., and Scipiades, E., Jr. Noninvasive Potential "Carcinoma" of the Cervix. *Am. J. Obst. & Gynec.*, 39:167, 1940. (Abstract of their original paper in *Surg., Gynec. & Obst.*, 66:822, 1938.)

Taylor, H. C., Jr., and Guyer, H. B. Seven Year History in Early Cervical Cancer. *Am. J. Obst. & Gynec.*, *52*:451, 1946.

Younge, P. A., et al.. A Study of 135 Cases of Carcinoma in Situ of the Cervix at the Free Hospital for Women. *Am. J. Obst. & Gynec.*, 58:867, 1949.

tion in the younger age group If the patient is 40 years of age or over, total hysterectomy may be an elective procedure rather than cauterization of the cervix In other instances, if there are indications for hysterectomy other than the presence of a preinvasive carcinoma, we concur in the advisability of total hysterectomy. The treatment of each patient should be individualized.

At the present we are at a loss to know exactly what to advise in cases of pregnancy. If biopsy can be safely performed after a patient has had a positive Papanicolaou stain, we think that this is indicated in order to determine whether or not invasion is present. If there is absence of invasion, we feel warranted in keeping the patient under close observation but allowing the pregnancy to proceed normally. After delivery, careful studies both by cytology and by biopsy should be made of the cervix and treatment carried out as recommended above.

REFERENCES

Auerbach, S. H, and Pund, E. R. Squamous Metaplasia of the Cervix Uteri. *Am. J. Obst & Gynec*, *49* 207, 1945

Ayre, J E Cervical Cytology in the Diagnosis of Early Cancer, *J A M A*, *136* 513, 1948.

Ayre, J. E, and Ayre, W B Progression from Precancer Stage to Early Carcinoma of the Cervix within One Year, Combined Cytologic and Histologic Study, with Report of a Case *Am J Clin Path*, *19* 770, 1949

Ayre in Cancer Diagnosis. Glycerine Technic

Boyc Cancer. *Am J Clin Path.*, *19* 341, 1949

Chung, J Detection of Uterine Carcinoma by Vaginal Smear Method *Quart Bull Northwestern Univ. M School*, *23* 33, 1949

Diddle, A W, et al Non-invasive Cervical Carcinoma, Clinical Features *Am J. Obst & Gynec*, *57*:376, 1949

Foote, F. W, and Li, K Smear Diagnosis of in Situ Carcinoma of the Cervix *Am J Obst & Gynec*, *56* 335, 1948

Galvin, G A, and Te Linde, R W Present-day Status of Non-invasive Cervical Carcinoma *Am J Obst & Gynec*, *57* 15, 1949

Gates, O, and Warren, S. Vaginal Smear in Diagnosis of Carcinoma of Uterus *Am J Path*, *21* 567, 1945

Gates, O, MacMillan, J C, and Middleton, M Vaginal Smear as a Means of Investigating Early Carcinoma of the Cervix *Cancer*, *2* 838, 1949

Goldberger, M. A, and Mintz, N Early Carcinoma of the Cervix, Its Pathological and Clinical Aspects *J Mt Sinai Hosp*, *14*·784, 1947

Graham, R M., and Meigs, J V Value of the Vaginal Smear. *Am J Obst. & Gynec*, *58* 843, 1949

Gusberg, S B Detection of Early Carcinoma of the Cervix, the Coning Biopsy *Am J Obst & Gynec*, *57* 752, 1949

Heyman, J Annual Report (League of Nations, Health Organisation) on Results of Radiotherapy in Cancer of the Uterine Cervix, Statements of Results Obtained in 1931 and Previous Years (Collated in 1937) *Acta obst et gynec. Scandinav (supp. 2)*, *18* 1, 1938.

Hunter, W C, and Richardson, H L Personal Communication

Ikeda, K The Papanicolaou Method of Cancer Diagnosis, An Evaluation *Minnesota Med*, *32*.54, 1949

Isbell, N P, et al Correlation Between Vaginal Smear and Tissue Diagnosis in 1,045 Operated Gynecologic Cases *Am J Obst & Gynec*, *54*.576, 1947

Knight, R V Superficial Noninvasive Intraepithelial Tumors of the Cervix *Am. J. Obst. & Gynec*, *46*.333, 1943

Kraushaar, O. F, et al. Vaginal Smear in Population Screening for Uterine Carcinoma *Am. J Obst & Gynec*, *58*.447, 1949

In the six year period from 1943 to 1948, 8,160 women were studied by vaginal smear at the Vincent Memorial Laboratory of the Massachusetts General Hospital. There were 432 cancers of the cervix and of these, 40 were classified as preinvasive. It is this group of 40 cases which we are to discuss here.

The vaginal smear was positive in 35, or 87.5 per cent, and negative in 5, a false negative percentage of 12.5 per cent. Twelve of these patients had cervices which were somewhat suspicious of cancer and a biopsy was taken at the same time as the first vaginal smear. However, in the remaining 28 or 70 per cent, the patients were thought to be without any suspicion of disease clinically, and the positive vaginal smear was the only evidence that they might have an early carcinoma. *We have found that the majority of the cases which are regarded as unsuspected and discovered by the cytologic examination of the vaginal smear are preinvasive carcinomas.* We have 38 cases which are classified as unsuspected, i.e., without clinical signs or symptoms of uterine cancer. Twenty-eight of them were histologically carcinoma in situ and 10 were invasive carcinoma.

In Table I is a list of the cases of carcinoma in situ which have been studied by the cytologic method. We have made no attempt to differentiate between vaginal, cervical, cervical scraping, or endocervical smears. It is our opinion that any *of these methods are satisfactory and the choice is a matter of individual preference.* We have limited our study almost entirely to the vaginal secretion and found it satisfactory One great advantage of the vaginal smear is the ease with which material may be obtained.

TABLE I

DIAGNOSIS OF CARCINOMA IN SITU BY CYTOLOGY

Author	*Year*	*No of cases*	*No of positive reports*	*No. of negative reports*
Papanicolaou and Traut	1943	7	7	0
Gates and Warren	1945	1	1	0
Isbell et al	1947	13	8	5
Ayre	1948	36	36	0
Foote and Li	1948	18	14	4
McSweeney	1948	1	1	0
Ayre	1949	1	1	0
Chung	1949	2	2	0
Diddle et al	1949	4	3	1
Graham and Meigs	1949	40	35	5
Gusberg	1949	1	1	0
Ikeda	1949	4	4	0
Kraushaar et al	1949	7	7	0
Nieburgs and Pund	1949	34	34	0
Schram and Di Palma	1949	1	1	0
Skapier	1949	21	19 (or suspicious)	2
Younge et al	1949	18	14	4
Hunter and Richardson	1949	1	1	0
		210	189	21

Table I clearly indicates that the cytologic method has focused attention on these *preinvasive carcinomas The first reported cases with positive cytologic reports* were those described by Papanicolaou and Traut in their monograph in 1943. Since that time an increasing number has been collected, until in the two years 1948 and 1949 alone 189 cases were reported as studied by the vaginal

Carcinoma in Situ of the Cervix: the Cytologic Method in Diagnosis and Study

RUTH M. GRAHAM

PRESENT CURE RATES *for carcinoma of the cervix are far from satisfactory. One* of the recent reports by Munnell and Brunschwig on a large series of cases from Memorial Hospital presents a five year cure rate of 28.6 per cent for the total of cases in all stages of the disease. This differs very little from Heyman's figures of the League of Nations Report of 1938, though the lapse of time is 10 years. However, if the cervical carcinomas are subdivided according to the extent of the disease, the stage I cases do much better, 53 per cent five year cures. It has become an obvious and almost trite fact that the chance of cure depends on early discovery. Because of the interest in early diagnosis, the small group of cases diagnosed histologically as carcinoma in situ or preinvasive carcinoma has assumed increasing importance.

Since the cytologic examination of the vaginal smear has been heralded as a method which is extremely valuable in the diagnosis of early carcinoma of the cervix, it is natural to inquire into its validity in this earliest of all lesions, the preinvasive carcinoma of the cervix. It is the purpose of this paper to assess, if possible, the usefulness of the method in discovering such lesions both from our own experience and from reports of other clinics. We would also like to suggest that the vaginal smear may be an excellent method of investigating the behavior of these early neoplasms. Because our only measure of the accuracy of the cytologic method must be an evaluation of its report against that of the histologic section, we must of necessity accept all the pathologic reports as bona fide preinvasive carcinomas Since the cellular changes which constitute a carcinoma in situ vary with the pathologist, it is recognized that perhaps some of the diagnoses would be interpreted differently under other circumstances. However, until agreement is more general, we see no alternative to accepting these diagnoses as truly representing preinvasive carcinoma.

Doubt has been expressed that a sufficient number of cells for recognition will desquamate from the small preinvasive carcinoma. Cytology is, of course, on much safer ground if positive diagnoses are made on numbers of desquamated cancer cells, rather than on the basis of one or two. It has been our experience that in general more malignant cells are found in these early cases than in the late stages of invasive carcinoma. It must be remembered that the method depends on the presence of well preserved cells. They are more likely to be present when the surface of the tumor is well nourished, as in the early lesions, than in the late cases where the surface is often necrotic.

In the six year period from 1943 to 1948, 8,166 women were studied by vaginal smear at the Vincent Memorial Laboratory of the Massachusetts General Hospital. There were 432 cancers of the cervix and of these, 40 were classified as preinvasive. It is this group of 40 cases which we are to discuss here.

The vaginal smear was positive in 35, or 87.5 per cent, and negative in 5, a false negative percentage of 12.5 per cent. Twelve of these patients had cervices which were somewhat suspicious of cancer and a biopsy was taken at the same time as the first vaginal smear. However, in the remaining 28 or 70 per cent, the patients were thought to be without any suspicion of disease clinically, and the positive vaginal smear was the only evidence that they might have an early carcinoma. We have found that the majority of the cases which are regarded as unsuspected and discovered by the cytologic examination of the vaginal smear are preinvasive carcinomas. We have 38 cases which are classified as unsuspected, i.e., without clinical signs or symptoms of uterine cancer. Twenty-eight of them were histologically carcinoma in situ and 10 were invasive carcinoma.

In Table I is a list of the cases of carcinoma in situ which have been studied by the cytologic method. We have made no attempt to differentiate between vaginal, cervical, cervical scraping, or endocervical smears It is our opinion that any of these methods are satisfactory and the choice is a matter of individual preference. We have limited our study almost entirely to the vaginal secretion and found it satisfactory. One great advantage of the vaginal smear is the ease with which material may be obtained.

TABLE I

DIAGNOSIS OF CARCINOMA IN SITU BY CYTOLOGY

Author	*Year*	*No of cases*	*No of positive reports*	*No. of negative reports*
Papanicolaou and Traut	1943	7	7	0
Gates and Warren	1945	1	1	0
Isbell et al	1947	13	8	5
Ayre	1948	36	36	0
Foote and Li	1948	18	14	4
McSweeney	1948	1	1	0
Ayre	1949	1	1	0
Chung	1949	2	2	0
Diddle et al	1949	4	3	1
Graham and Meigs	1949	40	35	5
Gusberg	1949	1	1	0
Ikeda	1949	4	4	0
Kraushaar et al	1949	7	7	0
Nieburgs and Pund	1949	34	34	0
Schram and Di Palma	1949	1	1	0
Skapier	1949	21	19 (or suspicious)	2
Younge et al	1949	18	14	4
Hunter and Richardson	1949	1	1	0
		210	189	21

Table I clearly indicates that the cytologic method has focused attention on these preinvasive carcinomas. The first reported cases with positive cytologic reports were those described by Papanicolaou and Traut in their monograph in 1943. Since that time an increasing number has been collected, until in the two years 1948 and 1949 alone 189 cases were reported as studied by the vaginal

Carcinoma in Situ of the Cervix: the Cytologic Method in Diagnosis and Study

RUTH M. GRAHAM

PRESENT CURE RATES for carcinoma of the cervix are far from satisfactory. One of the recent reports by Munnell and Brunschwig on a large series of cases from Memorial Hospital presents a five year cure rate of 28.6 per cent for the total of cases in all stages of the disease. This differs very little from Heyman's figures of the League of Nations Report of 1938, though the lapse of time is 10 years. However, if the cervical carcinomas are subdivided according to the extent of the disease, the stage I cases do much better, 53 per cent five year cures. It has become an obvious and almost trite fact that the chance of cure depends on early discovery. Because of the interest in early diagnosis, the small group of cases diagnosed histologically as carcinoma in situ or preinvasive carcinoma has assumed increasing importance.

Since the cytologic examination of the vaginal smear has been heralded as a method which is extremely valuable in the diagnosis of early carcinoma of the cervix, it is natural to inquire into its validity in this earliest of all lesions, the preinvasive carcinoma of the cervix. It is the purpose of this paper to assess, if possible, the usefulness of the method in discovering such lesions both from our own experience and from reports of other clinics. We would also like to suggest that the vaginal smear may be an excellent method of investigating the behavior of these early neoplasms. Because our only measure of the accuracy of the cytologic method must be an evaluation of its report against that of the histologic section, we must of necessity accept all the pathologic reports as bona fide preinvasive carcinomas. Since the cellular changes which constitute a carcinoma in situ vary with the pathologist, it is recognized that perhaps some of the diagnoses would be interpreted differently under other circumstances. However, until agreement is more general, we see no alternative to accepting these diagnoses as truly representing preinvasive carcinoma.

Doubt has been expressed that a sufficient number of cells for recognition will desquamate from the small preinvasive carcinoma. Cytology is, of course, on much safer ground if positive diagnoses are made on numbers of desquamated cancer cells, rather than on the basis of one or two. It has been our experience that in general more malignant cells are found in these early cases than in the late stages of invasive carcinoma. It must be remembered that the method depends on the presence of well preserved cells. They are more likely to be present when the surface of the tumor is well nourished, as in the early lesions, than in the late cases where the surface is often necrotic.

smear. This represents a substantial increase in the recognized incidence of carcinoma in situ. *Table II lists the total number of cases with a diagnosis of carcinoma* in situ by biopsy before treatment. In the 15 year period (1933-1949), 365 cases were reported. Obviously, the cytologic method is of great importance in the discovery of these early lesions. The positive report from either vaginal or cervical secretions makes a biopsy imperative. This factor alone probably accounts for many of the cases reported. In the absence of a cytologic report it appears unlikely that many of the cervices would have been biopsied. The cytologic method is of real importance in that it selects patients for biopsy.

It is pertinent to mention the accuracy of biopsy in these early lesions. In our own series we found the first smear to be correct in 87.5 per cent of the cases, the first biopsy in 70 per cent. We feel that the cytologic method is somewhat more accurate than the routine biopsy in this group of cases. This may be explained by the fact that *a smear is a representative sample of cells from the entire surface of* the cervix. Biopsy necessarily is limited by the size of the specimen removed. Many of the preinvasive lesions present no suspicious area and it is difficult to choose the site where tissue is to be removed. Both methods have a highly useful place *in the diagnosis of the preinvasive lesion.*

The accuracy of the smear in diagnosing all cases of carcinoma in situ as reported in the literature is 90 per cent. We have not been able to determine whether this is on the basis of one or more smears per case since in many papers the method of evaluation is not given. However, in our own series, the evaluation is on the basis of the first smear and the accuracy of these (87 5 per cent) is comparable to that of the collected cases. The obvious value of the cytologic examination of cervical or vaginal fluid in the diagnosis of preinvasive carcinoma cannot be denied. In fact, the increase in detection of early lesions by cytology may be the most important contribution of the method

It has been shown above that cytology is important and accurate in detecting cases of preinvasive carcinoma. We would also like to suggest that it may be of importance in investigation of the behavior of this entity Gates, MacMillan, and Middleton *in an interesting paper say. "We believe that the vaginal smear is an* ideal means of studying the development of carcinoma in situ or early carcinoma of the cervix. . . ."

Since the earliest reports of a cervical lesion which was described as a preinvasive carcinoma, there has been much discussion as to whether this represented a true carcinoma The question has been raised time and time again as to whether all these lesions possessed the capacity to become invasive and thus be classified as a true carcinoma. At the present there is fairly general agreement that they represent the earliest form of cervical carcinoma. However, there still remains a small group of cases in which the patient is cured by biopsy or inadequate treatment There has been much emphasis in the past few years on the case of carcinoma in situ which developed to invasive carcinoma over a period of years. But little attention has been paid to the cases which did not. It seems to us that these cases are worthy of attention

In Table II we have tabulated the cases of carcinoma in situ proved by biopsy before treatment A sufficient length of time has not lapsed to be able to evaluate the cases discovered by vaginal smear from a clinical standpoint. For the clinical

TABLE II

End Results of Therapy in Carcinoma in Situ of the Cervix

Author	Year	Total No. of cases	Adequate Treatment: Radiation	Adequate Treatment: Hysterectomy	Adequate Treatment: Modified Wertheim	Adequate Treatment: Well without disease	Inadequate Treatment: Amputation	Inadequate Treatment: Cautery	Inadequate Treatment: Trachelorrhaphy	Inadequate Treatment: Well without disease	Biopsy alone	Well without disease
1. Schmitz and Benjamin	1934	9	8			8	1			0		
2 Pemberton and Smith	1934	15	11			10			4	0		
3 Schiller	1938	51			51	49						
4. Stevenson and Scipiades	1938	16	6			6	1	2	5	7	2	1
5 Knight	1943	14	11			10	1			1	2	1
6 Rubin	1945	2	1			0					1	1
7 Taylor and Guyer	1946	1									1	0
8 McGraw	1947	1									1	1
9 Goldberger and Mintz	1947	2					1			1	1	0
10 Pund et al	1948	27	12	6		18	2	6		8	1	0
11 Galvin and TeLinde	1949	75	7		67	73	1			1		
12. Scheffey	1949	7									7	6 *
13 Diddle et al	1949	8		2		2		1		1	5	3
14 Younge et al.	1949	135		80 †		79 ‡		43	4	29	8	5
Totals		363	56	8 + 80 †	118	255	7	52	13	48	29	18
			262									
Cure rate						97%				67%		62%

* These 6 patients had conization of their cervices after biopsy and no tumor was found They are free of disease several years after original diagnosis
† Individual cases are not listed with follow-up.
‡ Does not include 4 intercurrent deaths

may apply that same rule to these early lesions? Cells which are morphologically identical to carcinoma cells that may revert to normal deserve the closest attention in cancer research. We should be able to elucidate important details of the behavior of early carcinoma.

The study of these cases is of first importance and if all are operated on without extensive study, we as a group have neglected a real opportunity to increase the knowledge of beginning cancer. The cytologic method may be the optimal way to study this problem. The cases could be followed and secretion obtained as often as desired. Morphologic changes in the cells could be observed. The simplicity of the method makes it an ideal one for an investigation of this nature.

Since the cases of preinvasive carcinoma appear to react differently clinically, we reviewed our own series to see if any difference could be discovered in the morphology of the cells. In the usual case of invasive squamous carcinoma the positive vaginal smear contains both undifferentiated and differentiated malignant cells. The undifferentiated malignant cells have an increase in chromatin, an aberration of the chromatin structure and vary in size and shape. The undifferentiated carcinoma cells are identified by the absence of a cell border. The cytoplasm is present in strands and if the cells are in a group they appear to share the background of cytoplasm, but it is impossible to determine cellular outlines. Nuclear outlines are sharp but the cell borders are not present. The differentiated carcinoma cells are distinguished from the undifferentiated cells by the presence of a cell border and a distinct shape. They are of three types, fiber, tadpole, and round. The nuclear structure of these malignant cells is similar to that of the undifferentiated It is only in the presence of cytoplasm and the shape of the cells that they may be identified as differentiated cells. The third type of differentiated cell, round in shape, is the malignant cell which most closely resembles the normal. It is circular, the size of a small basal cell. Its cellular border is definite and its cytoplasm dense and homogenous. These cells appear singly and only rarely in groups This cell resembles the normal basal cell in everything but its nuclear structure, which is of a definite malignant character. The chromatin is increased, and is irregularly arranged in dense clumps or heavy strands. The nucleus has a heavy border since a great amount of chromatin is condensed at the periphery. The surface of the nucleus often appears wrinkled. There is usually less cytoplasm than normal in these cells but one may occasionally encounter cells with a perfectly normal cytoplasmic nuclear ratio. It is only on the structure of the nucleus that these cells may be identified as malignant. As was mentioned above the common positive smear from invasive carcinoma has all these types of cells. Undifferentiated cells are present, fiber cells and the third type of differentiated cell. Tadpole cells are encountered infrequently.

In reviewing the positive smears on 20 cases of carcinoma in situ, we found that half of them had smears which were not different in any respect from those seen in invasive squamous carcinoma Undifferentiated cells were present, fiber cells, occasionally tadpole, and always the third type of differentiated cell. On the basis of the cellular picture as seen in the smear there was nothing to suggest that the carcinoma might be an extremely early one. Figure 1 shows a typical group of undifferentiated cells found in one of these cases. The patient had an

appraisal, we must depend on cases diagnosed by biopsy, which have been divided into groups according to the therapy received. Total hysterectomy, a modified Wertheim hysterectomy, and roentgen ray and radium therapy have been regarded as adequate treatment. Amputation of the cervix, cauterization, and trachelorrhaphy have been regarded as inadequate treatment. The group of cases which have had biopsies alone is considered separately. A case which was not followed for a sufficient length of time has not been listed in any of the three categories We have not included the cases of carcinoma in situ found by reviewing large numbers of pathologic material, unless the follow-up of these cases was discussed This review of the cases in the literature should not be regarded as exhau literature. However, during the past 20 years and represents a large enough series to enable one to draw some conclusions.

It is evident from Table II that cases of carcinoma in situ treated adequately do extremely well. The recurrence in the group with adequate treatment is only 3 per cent, an extraordinarily low figure. It is interesting that when the groups receiving inadequate treatment and those with biopsy alone are compared the figures are similar. The biopsy group showed a cure rate of 62 per cent, the inadequate treatment group a cure rate of 67 per cent

It is these last two groups which we should like to discuss, especially those patients who had biopsy alone In the past it has always been assumed that the biopsy removed the entire lesion This was the most obvious explanation for the absence of any tumor, but it does not appear to be entirely justified. It appears unlikely that the entire tumor would be removed by random biopsy in approximately 60 per cent of the cases. On the basis of chance alone this possibility is remote In addition, cervical amputation or cautery was followed by no better cure rate than biopsy—a remarkable coincidence if the eradication of carcinoma in situ is dependent entirely on external treatment If the therapy were the only factor operating, one might logically expect better results from amputation than from biopsy. Thus, it would seem that about 40 per cent of the patients with preinvasive carcinoma go on to develop a truly invasive tumor. But what of the other 60 per cent who are free of disease even though the treatment was poor by present standards? Can we assume that in every instance the entire tumor was removed by these minor procedures? Younge, Diddle, Pund, and their co-workers have described lesions which histologically are identical with carcinoma in situ occurring in pregnancy and disappearing post partum Are these tumors genuine preinvasive carcinomas? It appears to us that the answer to these questions is that the tumor may in some instances be reversible We realize that this is raising again the old issue of whether these tumors are all true malignancies, i.e, whether they possess the potentiality of invasion and if uninterrupted will continue to infringe on normal tissue. Certainly the amazingly high cure rate of these lesions if treated adequately is a powerful argument for definitive radiation or surgery. But, on the other hand if these tumors are reversible, it is of great importance. It would mean that perhaps there is a stage where the tumor may progress in either direction. Certainly it is well known that when a tumor becomes invasive it only progresses toward more invasion if untreated. But can we be sure that we

cells and are photomicrographs taken of vaginal smears from 2 patients with a histologic diagnosis of carcinoma in situ. Again the lesion was small and both patients were asymptomatic. The positive vaginal smear was the reason that biopsies were obtained. This picture of single, well differentiated cells among benign superficial cells is one which has impressed us as often being consistent with a carcinoma in situ.

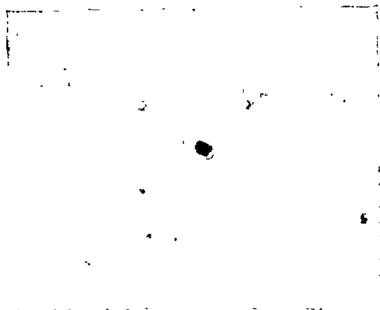


FIG 3 –A single differentiated cancer cell Cytoplasm and a distinct cellular border are present. The nucleus is hyperchromatic.

Thus from study of the morphology of the desquamated cells of these preinvasive lesions we are able to divide them into two categories, one indistinguishable from bona fide invasive carcinoma and the other characterized by a particularly well differentiated carcinoma cell as the only cytologic evidence of malignancy. The percentage correlation between the group containing well differentiated, malignant cells and the biopsy group which did well clinically is an interesting one, i.e., 50 per cent and 62 per cent It appears important to determine if this is a real correlation

We should like to suggest that it is this group of cases with well differentiated, malignant cells which should be thoroughly studied The first group which has smears indistinguishable from those of true invasive carcinoma would appear to have all the characteristics of virulent malignancy from a morphologic point of view. But since there are two different groups both clinically and cytologically, it is important to discover if there is a relation between the morphology of the malignant cells and the clinical course

We have some evidence that the carcinoma in situ containing only well differentiated cells may be reversible In November, 1947, a 37 year old white female presented herself at the Gynecologic Out-patient Department. Two vaginal smears taken a week apart were reported as positive and consistent with squamous carcinoma. The malignant cells were the round differentiated variety described above. They appeared singly in groups of benign superficial cells. A photomicro-

early preinvasive carcinoma. It was discovered by a vaginal smear taken at the time of a routine physical examination. The patient was without symptoms.

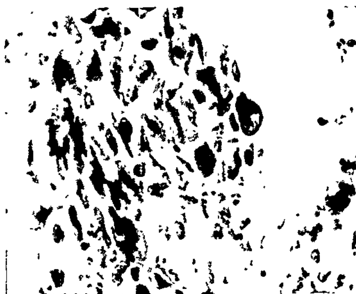


FIG 1 —A group of undifferentiated cancer cells, showing marked variation in size, shape, and chromatin content. Cellular borders are absent

The smears from the remaining 10 patients with carcinoma in situ showed an entirely different picture. There were no undifferentiated, fiber, or tadpole cells. The only cells present in the smear were the third type of differentiated cell, the small round malignant cell with a good cytoplasmic border which resembles the normal basal cell in everything but nuclear structure They appeared singly for the most part in a group of benign superficial cells. Figures 2 and 3 show these

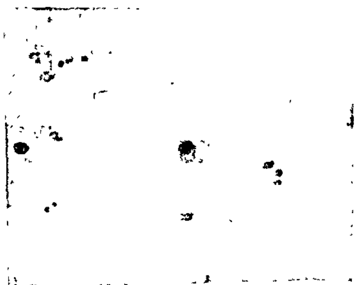


FIG 2 —A single differentiated cancer cell with cytoplasm and a sharp cellular border. The chromatin content of the nucleus is increased

entire lesion. It is not our purpose to suggest that all cases of preinvasive carcinoma be studied. The results of adequate treatment are so satisfactory that it would be irrational to defer treatment in all cases. It is our impression that all patients whose smears contain undifferentiated malignant cells should receive definitive therapy. The cases whose smears contain only single, well differentiated round cells might be followed at frequent intervals for a year. Any change in cell morphology, i.e., toward undifferentiation, would indicate immediate treatment. The growth of these lesions is known to be slow and such studies would have only a small element of risk. As cytology is discovering many more of these noninvasive tumors, the number of cases available for study will increase.

Boyd in a discussion of cytology and carcinoma in situ has said, "The question is, are we not dealing with reversible changes? I feel that this is going to be one of the great contributions which this method is going to make in the future. By this means, we can determine day by day, week by week, and month by month what is going on."

The reliability of the cytologic method in designating the proper cases for biopsy is unquestioned, but its use in studying early cancer should not be overlooked. The gynecologist has a unique opportunity to advance our knowledge of malignant disease by following at least some of these early lesions and it is he who must answer the difficult question of whether to operate on all the preinvasive lesions and "make assurance double sure" or to sacrifice a small degree of safety in anticipation of future dividends. We ask that this problem be given serious consideration.

graph of one of the cells is shown in Fig. 4. A biopsy of the cervix was performed and the report was "chronic cervicitis, ? carcinoma in situ." The patient was sent home with instructions to return to the clinic at two week intervals. However, she failed to appear and was not seen again until six months later. Repeated vaginal smears at that time were negative. Because of the previous positive vaginal smears and suspicious biopsy, a hysterectomy was performed. No evidence of any pre-invasive carcinoma was found. This may appear to be questionable evidence since an obvious criticism is that the biopsy was not definitely positive and misinterpretation of the exfoliated cells is an obvious answer. However, during a two year period, 122 cases were diagnosed by smear as positive and consistent with squamous carcinoma. All proved to be squamous carcinoma of the cervix. Since we cannot see any characteristics to distinguish the cells seen in this case from any other third type of differentiated cells of squamous carcinoma, we assume that the lesion was reversible.

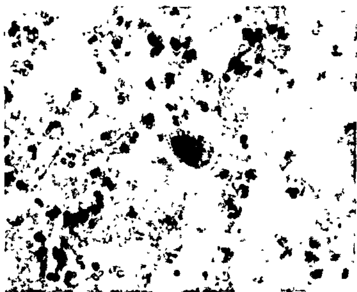


FIG 4 —A single cancer cell with a hyperchromatic, irregular nucleus and a sharp cellular outline. Note similarity of this cell to those shown in Figs 2 and 3.

It is important to collect more cases of this sort. Many questions remain to be answered Is the distinctive morphology of undifferentiated and differentiated cancer cells related to ability to invade surrounding tissues? Is the loss of cellular border and the sharing of cytoplasm by a group of nuclei correlated with the invasive properties of cells? Though metastatic implants and beginning invasion may not necessarily be caused by the same cellular components, it is interesting that in positive ascitic or pleural fluids, the desquamated cells seen are always of the undifferentiated type though the original tumor was a squamous carcinoma and presented both differentiated and undifferentiated elements.

It is conceivable that these problems might be answered if at least some cases of carcinoma in situ were followed for a sufficient length of time by cytologic means. At least we could answer the question of whether biopsy does remove the

Cholangiography *

PHILIP F. PARTINGTON, M.D., AND MAURICE D. SACHS, M.D.

INTRODUCTION

Cholangiography is the roentgenographic visualization of the biliary duct system by the injection of a radiopaque medium. It may be classified as "operative" or "postoperative," depending on the time of its performance, whether during or following surgery. In operative cholangiography, the radiopaque medium is introduced by needle, cannula, or catheter into the gallbladder or directly into the common bile duct before exploration of the duct. It may also be introduced through a T-tube following exploration of the duct to assure the removal of all calculi. In postoperative cholangiography, the radiopaque medium is usually introduced through a T-tube under fluoroscopic control in the roentgenray department several days to several weeks following surgery. The terms "operative" and "postoperative," originally used by Mirizzi, seem to be preferable to their equivalents, "immediate" and "delayed," used by Best and Hicken, and "primary," used by Hulten.

HISTORICAL

Operative cholangiography was performed for the first time in June, 1931, by Dr. Pablo Mirizzi, Chief of the Surgical Clinic at the University of Cordoba, Argentina. He was motivated in the use of this procedure by the high percentage of painful sequelae which followed gallbladder surgery and by the vagueness of the causes of the poor results In 1936 and 1937, in the United States, Best, Hicken, and Hunt, as well as Robins, Hermanson, and Mixter, reported on the use of operative cholangiography In 1941, in Paris, they were followed by Bergeret and Caroli who combined operative cholangiography with simultaneous measurement of the pressure in the bile ducts In 1942, in Lyon, France, Mallet-Guy commenced a prolonged study of routine operative cholangiography under manometric control. There have been sporadic reports from other authors, but few surgeons or radiologists have actually made a determined effort to make cholangiography a useful adjunct to biliary surgery.

Best, Hicken, Hunt, and others have been of the opinion that cases suitable for operative cholangiography can be selected by clinical evaluation and operative findings. Mirizzi and Mallet-Guy, as well as the authors, however, have insisted

* Reviewed by the Dean's Committee, Western Reserve University School of Medicine, and published with the approval of the Chief Medical Director, Veterans Administration The statements and conclusions published by the authors are the result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Avoidance of Common Duct Exploration

Lahey has stated that opening the common duct does not increase operative mortality. This does not hold true for patients who are poor surgical risks owing to cardiac, pulmonary, or renal disease. It is a definite advantage to be able to avoid unnecessary common duct exploration in such patients, in spite of the presence of one or more of the accepted criteria for exploration.

Jaundice or a history of jaundice is not an uncommon finding in acute cholecystitis. Common duct exploration may be quite difficult if not hazardous in this condition owing to the vascular edematous tissue which at times obscures the cystic and common ducts. Exploration can be avoided if the bile ducts are shown to be free of calculi.

At times, it is necessary to differentiate between the jaundice of hepatitis and that of obstruction by an exploratory operation. Far less harm is done to the patient with hepatitis if the abdominal exploration can be terminated following a needle puncture of the common duct, than if the operation is prolonged by opening it.

Recognition of Noncalculous Obstruction

Recognition of noncalculous obstruction of the common duct is assuming ever-increasing importance. Colp, in 1944, estimated the frequency of the post-cholecystectomy syndrome of painful sequelae to be 25 per cent. Mirizzi, in 1945, placed the number of "bad results" following cholecystectomy at 30 per cent for adepts in the classic procedures of exploration. By means of operative cholangiography, postcholecystectomy sequelae in 1,000 patients operated on in the surgical clinic of the University of Cordoba were reduced to 4 per cent as reported by Urrutia. Mirizzi stated that functional disturbances could not be seen or palpated at operation. Instrumentally, "odditis" could not be distinguished from stricture of the papilla of Vater. Moreover, both "odditis" and pancreatitis were likely to be followed by the formation of new common duct stones, if the underlying pathology was not recognized and corrected. Choledochitis with generalized narrowing of the biliary duct system was difficult to recognize without the aid of operative cholangiograms. Lasala, in 1947, reported a case of stenosis of both hepatic ducts recognized by means of operative cholangiograms. Whatever the nature of the obstruction, it is obvious that it must be recognized and localized before instituting a logical curative procedure.

Differentiation of Carcinoma and Pancreatitis

The preoperative differentiation between a carcinoma of the pancreas or ampulla of Vater and a common duct stone with an area of surrounding chronic pancreatitis is generally impossible All too frequently, it is also impossible at the time of surgical exploration The differentiation is readily made by operative cholangiogram, and the unnecessary resection of the head of the pancreas can be avoided.

Anatomic Orientation during Secondary Operations

Reoperation of the biliary tract, whether for retained stones, stricture, or functional disturbances, is much more difficult and dangerous than is primary

that the best results are obtained when operative cholangiography is done as a routine procedure.

NEED FOR OPERATIVE CHOLANGIOGRAPHY

Postoperative cholangiography was done for the first time in 1926 by Saralegui Since then it has been performed in many clinics, probably because of the availability of the T-tube as a means of injecting the radiopaque medium. Even this procedure is not in universal use. Operative cholangiography, of necessity performed in the operating room during operations on the biliary system, requires forceful arguments to justify its routine use.

Overlooked Stones

The high incidence of biliary calculi which are overlooked by competent surgeons, with or without common duct exploration, emphasizes the need for such an improved diagnostic method as operative cholangiography. Mirizzi has pointed out that it is easy to miss small stones in the distal third of the common duct, if the pancreas is large and hard. During common duct exploration, it is possible to slip by a stone with an instrument, without detecting its presence, as well as to miss intrahepatic stones beyond the reach of instruments. Probes, scoops, irrigation, and suction are not infallible for the detection of stones. It may be impossible to pass an instrument into the duodenum when the distal common duct is constricted by chronic pancreatitis, yet the nature of the obstruction may be obscure.

Lahey stated that prior to 1926, at a time when the common duct was explored in 15 per cent of the patients subjected to cholecystectomy in his clinic, 10 per cent of common duct stones were overlooked. He likewise expressed the belief that if a stone were missed, it would probably be the one causing symptoms and eventually a fatality.

Of 5,000 necropsies studied by Young at the Massachusetts General Hospital, 67 of the deaths had followed gallbladder surgery. Common duct stones had been present in 44 of these cases, while overlooked stones still were present in 27 (61.3 per cent) of them at postmortem. Making all possible allowances for poor surgical risk patients where prolonged exploration was not desirable, overlooked common duct stones were acknowledged in 16 per cent of the series.

Bonn, in a study of 1,000 necropsies, found evidence of common duct calculi in 78 out of 325 cases containing gallbladder calculi. Stones at the ampulla were observed in 47 cases and hepatic calculi in 22. The author was of the opinion that, of 4 patients with calculi in the gallbladder, one would have a stone in the common duct, and there would be a 60 per cent chance that this stone would be retroduodenal. These data have been confirmed surgically by Clute and Kehr.

Schuberth and Sjogren, by the use of cholangiography, demonstrated residual common duct stones in 9 out of 27 cases in which the common duct had been explored. Several of these calculi were in the hepatic ducts. They also reported overlooked calculi in one-third of their patients who died following common duct exploration.

some of the frequent causes of failures. Almost all such failures occur in the early part of any given series of cases and become infrequent with increased experience. Misinterpretations can be avoided, for the most part, if the radiologist is present in the operating room for the reading of the wet films.

TECHNIC OF OPERATIVE CHOLANGIOGRAPHY

CONTRAST MEDIA

Of the numerous problems which arise in the performance of operative cholangiography, the choice of a suitable medium is of primary importance for the achievement of satisfactory results. To evaluate a specific medium the following criteria should be considered: adequate density, low viscosity, easy miscibility, and minimal degree of toxicity. Adequate density is needed to assure the accurate detection of all foreign bodies. Small opacities must not be obscured. Low viscosity is required, inasmuch as high viscosity media are difficult to inject, and interfere with a controlled rate of injection. Easy miscibility is desirable, since a medium which does not mix readily with bile will produce a film with incomplete visualization of the biliary system and lead to false positive interpretations. A minimal degree of toxicity is required, because some patients are allergic to certain media. If extravasation occurs, the medium should be readily absorbable and should not produce residual toxic effects.

Historical Review of Media Used. Many contrast substances have been advocated as suitable for cholangiography. The earliest media used were pastes of bismuth or barium. These were discarded because of the intense pain and febrile reactions that followed their use. Salts of potassium iodide, sodium iodide, and sodium bromide also proved to be irritants.

Since numerous identical contrast media have been used in recent years under different trade names and in other parts of the world, the more popular media, with equivalent trade names, firms, and chemical components are reviewed.

Lipiodol (LaFay) is a poppy seed oil containing 40 per cent iodine.

Lipiodine Diagnostic (Ciba) is a 60 per cent solution of iodobrassid in sesame oil

Iodochlorol (Searle) is an oil containing 36 to 42 per cent iodine

Thorotrast (Heyden of New York) is a 25 per cent stabilized colloidal suspension of thorium dioxide

Umbrathor (Heyden of Dresden) is a nonstabile colloidal suspension of thorium dioxide

Hippuran (Mallinckrodt) and jodairal 50 per cent (Swedish Apotakens Specialitetsregister) are sodium ortho-iodo-hippurates containing 34.95 per cent iodine Jodairal forte is a 60 per cent solution

Skiodan sodium (Winthrop-Stearns), abrodil, and myelotrast (Bayer) are methiodal sodium containing 52 per cent iodine.

Teneybryl (Bayer), available only in Europe, is the diodo analogue of skiodan sodium containing 68.6 per cent iodine

Neo-iopax or uroselectan (Schering) is a 50 or 75 per cent sodium iodomethamate containing 51 5 per cent iodine.

surgery Valuable time may be lost. It is of the utmost importance for the surgeon to be able to orient himself with respect to the distorted anatomy and pathology, by merely inserting a needle into the first bile-filled structure encountered, in order to obtain a cholangiogram.

REASONS FOR NONACCEPTANCE OF OPERATIVE CHOLANGIOGRAPHY

Distrust of New Procedures

New methods or technics are naturally greeted with some degree of skepticism. There is no weight of past experience and proved worth to counterbalance initial difficulties. It seems poor judgment to cast off tried and true methods, despite recognized shortcomings, for methods of doubtful merit Acceptance of operative cholangiography has likewise been slow, as considerable time has been required to surmount initial difficulties.

Lack of Teamwork and Interest

One of the major problems has been the lack of teamwork and interest on the part of the surgeon, radiologist, and anesthetist If the surgeon does not recognize the need for such a procedure, the radiologist will be confronted with considerable difficulty in establishing its use. If the radiologist is not interested, difficulties of availability of technicians and timing can seem insurmountable to the surgeon By inadvertently allowing slight respiratory motion during a roentgen ray exposure, the anesthetist can render the entire procedure meaningless, unless the surgeon is willing to undergo the exacting requirements of local anesthesia.

Inadequate Equipment

In the past, unsuccessful attempts have been made to use this procedure with inadequate equipment. Actually, little special equipment is required for taking operative cholangiograms. The only essentials are a portable roentgen ray machine of sufficient capacity to avoid unduly long exposures, a grid, and a plywood tunnel such as is used in hip nailing. Movement of any type, especially respiratory movement, has to be prevented for adequate diagnostic radiographs.

Procedure Not a Routine

In many hospitals, operative cholangiograms have been tried only in selected cases, with several unfortunate results. There is no adequate method of selecting cases, and those needing it most may be excluded Personnel associated with the procedure must be familiar with it to keep it from being unduly slow in execution. If essential equipment is missing or defective, if roentgen ray personnel is busy with other examinations, or if the tunnel is not under the patient, the entire examination may be abandoned because too much time would be lost in correcting these errors. Only by making the procedure a routine, can the necessary preparation, teamwork, speed, and accuracy be achieved.

Technical Inadequacies

Technically inferior films due to poor centering, improper exposure, motion of the patient, artefacts such as air bubbles, and extravasation of the medium are

either with a needle or cannula, as practiced by Mallet-Guy and others, is undoubtedly the most simplified method, providing the cystic duct is patent. Mallet-Guy demonstrated dysfunction of the cystic duct sphincter (Lütken's sphincter) by this method. This route of injection also has been used in association with peritoneoscopy to visualize the biliary tract without operation. The incidence of bile peritonitis following this procedure has prevented it from becoming popular in the United States. The chief disadvantages of injecting contrast media into the gallbladder include the large amount of medium required and the size of the resulting radiopaque density which may easily obscure a portion of the bile duct system. Mirizzi utilized the gallbladder for media injection in pseudotumoral cholelithiasis wherein the entire subhepatic space is occupied by an inflammatory mass with only the tip of the gallbladder presenting. He also used it in cases of jaundice of hepatic origin.

The cystic duct may be utilized to insert a cannula or catheter into the common duct. Because of wide variation in the size of the cystic duct, Mirizzi employed a variety of cannulae, some having large olive tips. If the cystic duct is very small, it may be necessary to dilate it carefully, as recommended by Mallet-Guy, before inserting the cannula. A cannula which impinges on the wall of the common duct opposite the cystic duct may produce a localized spasm, simulating a deformity of the duct in this region. The valves of Heister, at times, prove to be an obstacle in the insertion of a cannula or catheter. With patience, it is usually possible to discover the correct opening.

A ureteral catheter inserted through the cystic duct approximately 2 cm into the common duct and held in place by a ligature is a satisfactory method for injecting contrast media. This is probably one of the easiest methods and is recommended to those trying the procedure for the first time. The valves of Heister are usually negotiated with ease. The catheter is pliable enough to take the curve of the cystic duct and does not produce spasm of the common duct wall opposite the cystic duct. The use of a ligature enables the catheter to be used in even fairly large cystic ducts without leakage of contrast media.

Contrast media may also be introduced directly into the common duct by means of a short, fine gauge needle inserted through the anterior wall of the duct. If the gallbladder has been removed previously, this method is the only way of visualizing the bile ducts prior to exploration. A ½ inch No. 22 gauge needle with a short bevel and sharp point is satisfactory. It produces a small hole which leaks bile for only a short time after withdrawal of the needle. There may be some localized common duct spasm at the site of injection and likewise some distortion of the duct. This is especially true if the needle with its attached rubber tubing filled with contrast medium is angulated in an attempt to prevent obscuring the duct system. If the common duct is explored and a T-tube inserted, additional injections of media may be made directly through this tube.

Anesthesia

Any anesthetic agent suitable for the performance of biliary surgery is adequate for operative cholangiography. The importance originally attached to local or spinal anesthesia by Mirizzi and Best and Hicken was attributed to the need for complete respiratory arrest during roentgen ray exposure. Recent perfection of

Rayopake (Schering) is a solution of diethylanolamine salt containing 50 per cent iodine.

Diodrast (Winthrop-Stearns), 35 or 70 per cent, perabrodil (Bayer), and diodone, 35 per cent (British pharmacopeia) are iodopyracets containing either 25 or 49.8 per cent iodine.

Media containing oils, such as lipiodol, have not proved satisfactory. They are extremely difficult to inject, they interfere with a controlled rate of injection, and their density tends to obscure small calculi. If the medium fails to mix with bile, droplet formation and misinterpretation result. Saralegui has stated that lipiodol changed the function of the sphincter of Oddi.

Thorotrast or umbrathor produces the highest density, mixes easily with bile, and has a low viscosity. Its extravasation into the soft tissues causes a foreign body reaction. It is a radioactive material The objection is not so much its radioactivity if some dye should get into the blood stream and become absorbed by the reticulo-endothelial system, mostly liver and spleen, but the foreign body reaction caused by extravasation. Some authorities state that it is a carcinogenic agent.

Hippuran or jodairal, and skiodan or abrodil are safe media. They cause no iodine reaction, and the media are easily absorbed if extravasated. The density, however, is low.

Rayopake has not been tried because of its low density. Diodrast, 35 per cent, or neo-iopax, 50 per cent, are safe, easily absorbed, and have a low viscosity, but the density is somewhat low.

Diodrast, 70 per cent (perabrodil) or neo-iopax, 75 per cent, in our experience, has proved highly satisfactory The density is almost as high as that of thorotrast or lipiodol. They are easy to inject, low in viscosity, and rapidly absorbed if extravasated.

Pantopaque emulsion (Eastman Kodak) is a benzoic acid containing 52.9 per cent iodine It contains ethyl iodophenylundecylate, 50 per cent, dispersed in water. It has been used by Strain and Pirkey. The latter states that it is excellent for cholangiography It is easily injected, mixes readily with bile, does not break *up, nor does it produce false interpretations. It merits consideration for future* use.

Mirizzi has continued to use lipiodol as the medium of choice for almost 20 years. Hicken, Best, and Hunt used either lipiodol or hippuran. Mixter preferred hippuran. Saralegui advocated the use of thorotrast. Martensson, in a critical study of media used in cholangiography, stated that perabrodil (diodrast) was the safest and best substance.

It is apparent that no medium has met the prescribed criteria in their entirety. When the advantages and disadvantages are weighed, however, the media found to be most satisfactory in our experience during the past three and a half years, in a series of over 150 cases, have been 70 per cent diodrast and 75 per cent neo-iopax.

Methods of Injecting Contrast Media

Contrast media used in operative cholangiography may be introduced into the biliary tract in a variety of ways. Injection of the medium into the gallbladder,

either with a needle or cannula, as practiced by Mallet-Guy and others, is undoubtedly the most simplified method, providing the cystic duct is patent. Mallet-Guy demonstrated dysfunction of the cystic duct sphincter (Lütken's sphincter) by this method. This route of injection also has been used in association with peritoneoscopy to visualize the biliary tract without operation. The incidence of bile peritonitis following this procedure has prevented it from becoming popular in the United States. The chief disadvantages of injecting contrast media into the gallbladder include the large amount of medium required and the size of the resulting radiopaque density which may easily obscure a portion of the bile duct system. Mirizzi utilized the gallbladder for media injection in pseudotumoral cholelithiasis wherein the entire subhepatic space is occupied by an inflammatory mass with only the tip of the gallbladder presenting. He also used it in cases of jaundice of hepatic origin.

The cystic duct may be utilized to insert a cannula or catheter into the common duct. Because of wide variation in the size of the cystic duct, Mirizzi employed a variety of cannulae, some having large olive tips. If the cystic duct is very small, it may be necessary to dilate it carefully, as recommended by Mallet-Guy, before inserting the cannula. A cannula which impinges on the wall of the common duct opposite the cystic duct may produce a localized spasm, simulating a deformity of the duct in this region. The valves of Heister, at times, prove to be an obstacle in the insertion of a cannula or catheter. With patience, it is usually possible to discover the correct opening.

A ureteral catheter inserted through the cystic duct approximately 2 cm. into the common duct and held in place by a ligature is a satisfactory method for injecting contrast media. This is probably one of the easiest methods and is recommended to those trying the procedure for the first time. The valves of Heister are usually negotiated with ease. The catheter is pliable enough to take the curve of the cystic duct and does not produce spasm of the common duct wall opposite the cystic duct The use of a ligature enables the catheter to be used in even fairly large cystic ducts without leakage of contrast media.

Contrast media may also be introduced directly into the common duct by means of a short, fine gauge needle inserted through the anterior wall of the duct. If the gallbladder has been removed previously, this method is the only way of visualizing the bile ducts prior to exploration. A ½ inch No. 22 gauge needle with a short bevel and sharp point is satisfactory It produces a small hole which leaks bile for only a short time after withdrawal of the needle. There may be some localized common duct spasm at the site of injection and likewise some distortion of the duct. This is especially true if the needle with its attached rubber tubing filled with contrast medium is angulated in an attempt to prevent obscuring the duct system. If the common duct is explored and a T-tube inserted, additional injections of media may be made directly through this tube.

Anesthesia

Any anesthetic agent suitable for the performance of biliary surgery is adequate for operative cholangiography. The importance originally attached to local or spinal anesthesia by Mirizzi and Best and Hicken was attributed to the need for complete respiratory arrest during roentgen ray exposure. Recent perfection of

endotracheal general anesthesia, administered by a closed system, has made it easy to obtain respiratory arrest in the unconscious patient.

The anesthetist must assume considerable responsibility for the success of the procedure, however, as even slight motion is incompatible with good films. Following insertion of the intratracheal tube, the pharynx is packed tightly to prevent leakage in the system. As the operation progresses, the conversation of the surgeon is appraised by the anesthetists for signs designating the time to prepare for cholangiography. Approximately five minutes before the procedure is due to start, the anesthetist commences to control the patient's respirations by lowering the carbon dioxide tension. Pressure is made on the bag of the anesthesia machine in time with the patient's respirations, deepening them and slowing them down Finally, spontaneous respirations cease, and the anesthetist is able to suspend them at will for short periods. The ease with which respirations may be controlled varies considerably with different patients. Even with obese people, however, five minutes is generally sufficient to allow periods of respiratory arrest of three or four seconds.

The use of small doses of curare makes the control of respiration a great deal easier With a patient in third plane ether anesthesia, 20 to 40 units, or 3 to 6 mg., administered intravenously, usually is sufficient. With cyclopropane, doses of 40 to 60 units, or 6 to 9 mg, will probably be necessary. Even with the larger dose, spontaneous respirations will not cease, however, if the anesthetist does not control them manually as well. A determination of the time required to take over controlled respiration may be made early in the operation to ascertain the need for using curare.

Respirations are controlled for the entire period of cholangiography, following which the patient is allowed to resume spontaneous respirations. These are comparatively shallow at first but soon resume their normal character. If additional films are to be taken, respiration is again controlled in the same manner.

There is no conclusive evidence that the usual anesthetic agents have any direct action on the biliary duct system. Best and Hicken originally stated that spinal anesthesia caused a relaxation of the sphincter of Oddi, but later decided that it did not Mallet-Guy reported a rapid and profound drop in intrabiliary pressure following the use of sodium pentothal in dogs. In a limited use of this anesthetic agent in humans, we have been unable to confirm this observation. Mixter believed that the use of spinal anesthesia has no effect on the action of the sphincter of Oddi. The abnormal reaction of the bile ducts during anesthesia is manifested chiefly by alterations in the intraductal pressure. These pressure changes seem to be correlated with the use of preoperative medication such as morphine, or one of its derivatives, rather than with any anesthetic agent.

The explosion hazard associated with radiography under general anesthesia is negligible. This minimal danger may be reduced by having adequate shock-proof roentgen ray units and contact switches, and by giving anesthetic gases with a closed system technic. Danger of explosion may be further reduced by placing the control stand and transformer outside of the operating room with only the cables, tube, and portable bucky remaining inside. Worn cables should be replaced. The roentgen ray machine should be approximately 3 feet from the anesthesia unit on the opposite side of the operating table. As an added precau-

tion, a moist towel can be placed over the face mask prior to the roentgen ray exposure. A mechanically operated bucky diaphragm is adequate, since it would be too expensive to procure a spark-proof one.

EQUIPMENT

The equipment needed for operative cholangiography is readily available or easily fabricated. A shock-proof portable roentgen ray unit that may be operated at 80 to 90 kv. and 30 ma. at approximately 30 in. tube target distance, with an exposure time of one and a half to four seconds, is the prime essential. A portable 60 ma. unit will shorten the exposure, with a resultant improvement in the quality of the films. The faster the exposure, the less chance there is of technical error. Units operating at 15 ma. or less can be used, but the degree of accuracy may be decreased by respiratory motion.

A portable bucky or a plywood tunnel capable of holding a 10 x 12 in. or 14 x 17 in. cassette with a superimposed Lysholm grid is necessary It is placed on the operating table beneath the liver area of the patient to permit easy exchange of cassettes without movement of the patient. Folded sheets are used at either end of the tunnel or bucky to make the surface of the table level (Fig. 1A).

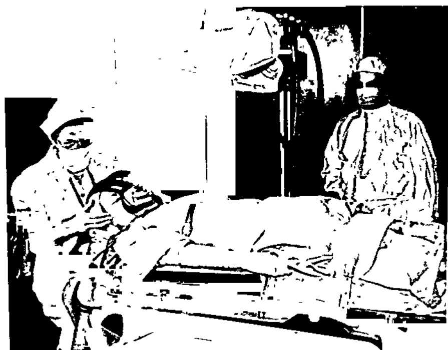


FIG 1A.—Portable bucky in position on the operating table with folded sheets at both ends of the bucky to make the table level Portable x-ray machine with the tube head covered by a sterile pillow case

The remaining equipment may be listed as follows·

Four 10 x 12 in. cassettes
One No. 22 gauge ¼-in needle with attached latex tubing
One No. 18 gauge intravenous cannula with attached latex tubing
One No. 6 ureteral catheter with adapter or injection tip
Two 30 cc. syringes

Twenty cc. of 70 per cent diodrast or 75 per cent neo-iopax warmed to 98° F.
Thermometer to measure temperature of radiopaque media.

Note: Before using, all rubber tubing should be checked for cracks and leaks, and needles should be checked for sharpness (Fig. 1B).

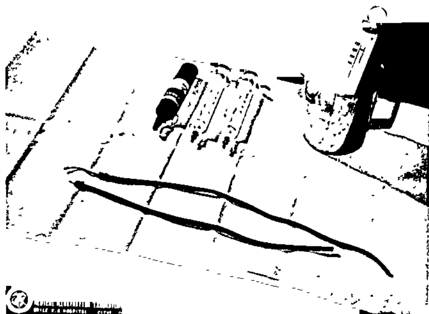


FIG 1B—Additional equipment necessary for operative cholangiography

ROENTGEN RAY TECHNIC

The roentgenographic requirements for operative cholangiography are easily met by any hospital x-ray department. While the technic is simple, it requires careful attention to detail

Correct positioning of the patient on the operating table is most important. The plywood tunnel with a Lysholm grid or the portable bucky must be centered accurately to the bile duct area. The patient is then rotated approximately 10° to the right by means of folded sheets under the left thorax and hip. This rotation is necessary to prevent the common duct from overlying the spine and being obscured by it.

A scout film is taken following positioning of the patient to check on the accuracy of the positioning and also to allow any necessary kilovoltage or milliamperage corrections to be made. The position of the portable x-ray machine is marked with adhesive strips on the floor of the operating room. This allows the unit to be wheeled rapidly into position with accurate centering of the x-ray tube to the bucky when films are to be taken during the course of the operation.

Technical factors depend on the size and adiposity of the patient. A short exposure is preferable in order to reduce the possibility of motion. Average exposures will vary from one and a half to four seconds and will be proportionately shorter if a higher energy unit is used.

A series of three exposures is made, one after each 5 cc. injection of the medium (see page 128 for additional detail). A darkroom adjacent to surgery is optimal but is hardly necessary unless the x-ray department and the operating rooms are widely separated. The surgeon usually continues with some phase of the operation during the 10 to 15 minutes required for transportation and development of the films.

The final and most important step in the process of operative cholangiography is the wet film reading in the operating room with the radiologist and the surgeon in consultation. Both surgeon and radiologist may become quite adept, individually, in the interpretation of cholangiograms, but only in consultation, can the various factors involved in a diagnosis come into proper focus for correct conclusions.

Operative Technic

Success in operative cholangiography is achieved by establishing a routine procedure which purposely avoids the recognized causes of poor films and misinterpretations. A common cause of poor films is the presence of radiopaque objects, such as towel clips and retractors, in the operative field during roentgen ray exposure. This may be avoided by sewing on both the towels used for draping the operative field and those used for excluding the skin. All instruments and retractors are removed from the wound prior to roentgen ray exposure.

A careful dissection of the junction of the cystic and common duct is necessary in order to occlude the cystic duct accurately without leaving a long stump between the tie and the common duct. Likewise, the common duct must be exposed sufficiently to allow insertion of a small needle through its anterior wall opposite the cystic duct junction without damaging the small veins lying on its surface. The cystic duct is occluded with a silk ligature if the surgeon is confident that the gallbladder is to be excised. In the event of doubt, as in cases wherein jaundice may be of hepatic origin, or in which the gallbladder may be required for anastomosis to the intestinal tract, the cystic duct is occluded by a single knot in an elastic band. The ends of the elastic are prevented from becoming untied by a silk ligature which can be cut to remove the elastic without damaging the cystic duct.

A ureteral catheter or an intravenous cannula may be inserted through the cystic duct stump if the gallbladder is to be excised. A ligature maintains them in the duct and prevents dye leakage. The ureteral catheter is connected by an adapter or injection tip to a 30 cc. syringe filled with saline warmed to 98° F. The catheter is likewise filled with saline before its insertion into the common duct. It should not be inserted more than 2 or 3 cm. to prevent common duct distortion.

The intravenous cannula is connected to 12 in. of new amber rubber tubing which, in turn, is connected to a 30 cc. syringe filled with warm saline. All air bubbles must be removed from the tubing, which is then clamped near the syringe before inserting the cannula into the cystic duct. If the tubing is kinked during this insertion, several drops of saline will be forced from it, allowing air bubbles to enter the cannula These must be expelled to prevent later misinterpretations. A curved cannula, as used by Mallet-Guy, is necessary to avoid some distortion at the junction of the common and cystic ducts.

If the gallbladder has been removed previously or if the advisability of its excision is in doubt, a ½ in. No. 22 gauge needle is inserted through the anterior wall of the common duct in the direction of the liver. This needle, in the same manner as the cannula, is connected to a 30 cc. syringe by means of amber rubber tubing filled with warm saline. Most common bile ducts are thin-walled and easily compressible. If great care is not exercised, it is not uncommon to insert the needle through both the anterior and posterior walls. The anterior wall of the common duct is picked up with the needle point, and the needle is leveled until it is almost parallel to the common duct before being inserted. There is a characteristic "pop" as the needle enters the duct. Withdrawal of the needle from the duct should be avoided, since multiple punctures allow leakage of opaque media, obscuring the operative field.

The position of the needle or cannula in the common duct is checked by the injection of a few cubic centimeters of saline There should be moderate resistance to the injection, but the fluid should enter the duct without infiltration of its wall It is rarely possible to aspirate bile through such a small needle. After the position of the needle is satisfactory, the amber rubber tubing is clamped near the syringe, and the syringe is exchanged for one filled with 70 per cent diodrast or 75 per cent neo-iopax warmed to 98° F. An air bubble is always introduced during this exchange and must be drawn up into the barrel of the syringe before starting the injection The amber tubing is arranged laterally so that no part of the biliary duct system will be obscured. All retractors and instruments are withdrawn from the wound, and the field is covered with a sterile sheet.

The contrast medium is injected slowly, in 5 cc. amounts. A series of three injections is made The injection, timed with a stopwatch, should require 30 to 45 seconds for each 5 cc. A rapid injection will distend the bile ducts and produce spasm of the sphincter of Oddi with consequent misinterpretation of any existing pathology Large ducts may be incompletely filled even after a total of 15 cc. of the media In such instances, it is preferable to make additional injections of 5 cc. each rather than to inject a large amount of the medium at one time with the possibility of obscuring small stones.

As the contrast medium is injected, the surgeon counts the cubic centimeters aloud to warn both the anesthetist and the technician of the impending exposure. At the count of five, the amber rubber tubing is clamped to prevent reflux into the syringe, and the surgeon turns from the operating table to avoid undue radiation exposure The anesthetist suspends respiration in inspiration by pressing on the bag of the anesthesia machine and signals to the technician who makes the exposure The cassette is then removed to a place where the next exposure will not fog it. This process is repeated with a change of cassettes after each exposure until a series of three films has been taken. The films are carried immediately to the x-ray department and processed in the usual manner.

During the 10 to possibly 15 minutes before the processed films are returned, the surgeon continues with the operation unless further procedure must await the results of the cholangiograms. The radiologist returns with the wet films, and their interpretation is made in the operating room in consultation with the surgeon. Although the surgeon may be competent in interpreting the films, if he

reads them alone, he may be unduly influenced by his operative findings and thus overlook significant features in the films.

If the common duct is explored, a repeat set of films is made through the T-tube before the abdomen is closed. A *double lumen T-tube (manufactured by C. R. Bard, Inc., Summit, N. J.)* facilitates the removal of air from the T-tube and common duct before injection of radiopaque media. Saline is injected through the large lumen of the T-tube until no further air returns through the small lumen. *The tube is then tied to the syringe adapter to occlude the small lumen and* prevent further leakage. The saline syringe is exchanged for one containing medium, and the injection is made. If a single lumen T-tube is used, a ½ in. No. 22 gauge needle should be inserted into the T-tube close to the common duct, and all air should be removed from the system with saline. The T-tube is then clamped and the injection of opaque medium is made through the needle into the T-tube.

Overlooked common duct calculi seen in cholangiograms made through a T-tube necessitate re-exploration of the common duct (Fig. 11B). Another set of films is made through the T-tube following this procedure to make certain that the common duct is clear of calculi

Importance of Teamwork

The importance of teamwork and interest cannot be overemphasized if operative cholangiography is to be successful. The procedure requires strict attention to many small details on the part of each individual concerned. Lack of interest in those details, impatience with the inevitable occasional poor result, failure in the early stages of an individual series, or poor co-ordination between the various members of the team can easily discredit the procedure before its true value has become apparent. Only by making operative cholangiography a routine procedure for all biliary surgery can the personnel involved become so proficient that the examination will be indispensable to the surgeon.

NORMAL ANATOMY OF BILIARY TRACT

The normal radiographic anatomy of the biliary tract corresponds quite closely to standard anatomic drawings (Fig. 2). The occasional wave-like or serrated appearance of the bile duct walls, interpreted by Mirizzi and Mallet-Guy as due to active peristalsis, constitutes a possible functional variation.

Intrahepatic Bile Ducts

The biliary duct system is divided into an intrahepatic and an extrahepatic portion The intrahepatic radicles begin almost at the surface of the liver as fine filiform ducts measuring less than 0 05 mm in diameter They are rarely filled with contrast media unless there is an obstruction of the extrahepatic ducts or transitory spasm of the sphincter of Oddi permitting a rise in biliary duct pressure up to 50 cm of water (Figs. 3 and 31) These radicles gradually increase in size and merge to form larger ducts until two main hepatic branches of almost equal size are formed The left branch is slightly larger than the right. It lies almost transversely near its origin in the periphery of the left lobe of the liver and extends in a gradual curve inferiorly to assume an almost vertical position.

The right hepatic duct joins the left at approximately a right angle. This junction may occur within the liver substance or just outside of it in the portal fissure of the liver.

Normal hepatic ducts vary in size between 3 and 5 mm. in diameter. Counseller and McIndoe, in a study of postmortem specimens, reported a normal diameter of

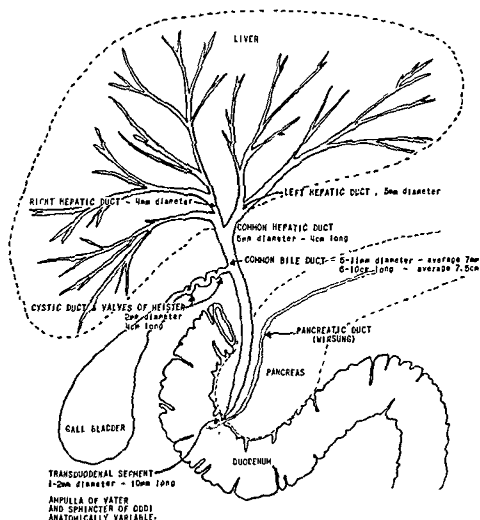
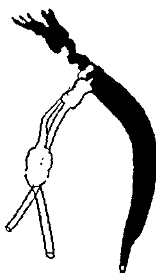


FIG 2.—Diagram of biliary ducts and their relation to adjacent viscera.

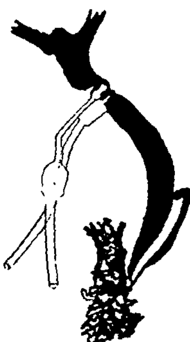
5 mm. The measurements described by Giordano and Mann, and our recent measurements of normal operative, postoperative, and postmortem cholangiograms were almost identical with this figure.

Extrahepatic Bile Ducts

The extrahepatic portion of the duct system consists of the terminal portions of the right and left hepatic branches, if they join outside of the liver, the common hepatic duct, gallbladder, cystic duct, and common bile duct. The common hepatic duct appears to be a direct, almost vertical continuation of the left

A

B

FIG 3.–D.N., a 51 year old white male with chronic cholecystitis and small stones in the gallbladder, no history of jaundice (A) Operative cholangiogram showing a slightly dilated common duct with a small calculus in the ampulla dislodged from the cystic duct by manipula- ... la in the cystic duct for manometry. ... ve cholangiogram after spontaneous ... of water. Medium in duodenum and pancreatic duct.

hepatic duct. It is approximately 4 cm. in length and 5 mm. in diameter. The gallbladder has been omitted from this study since, with the technic employed, the cystic duct was almost always occluded prior to the injection of the opaque medium Its visualization was considered to be of less importance than the possibility that its shadow might obscure a more important portion of the duct system The cystic duct extends from the neck of the gallbladder to the lateral wall of the common hepatic duct which it enters at an angle varying up to 90°. It measures approximately 3 to 4 cm in length and 2 mm. in diameter. Mucosal folds of varying degrees of development, called Heister's valves, are responsible for the occasional corkscrew appearance of the duct radiographically (Fig. 4).



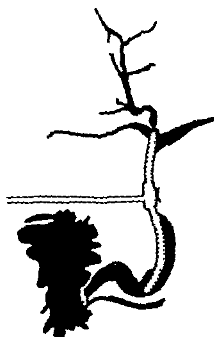
Fig 4—G W, a 54 year old white male treated with cholecystostomy for cholecystocolic fistula Postoperative cholangiogram (catheter in the gallbladder) showing well developed valves of Heister and a normal common duct

There may also be a more or less developed cystic duct sphincter known as Lutken's sphincter To demonstrate the presence of this sphincter radiographically, contrast media should be injected directly into the gallbladder.

The common bile duct extends from the junction of the cystic and hepatic ducts to the lower middle third of the descending duodenum. In this region, the duct enters the duodenum on its medial posterior wall to terminate in the major papilla. The duct describes a gentle curve with its convexity to the left. It varies in length from 6 to 10 cm., with an average of 7 5 cm, and, in diameter, from 5 to 11 mm, with an average of 7 mm. The common duct may be divided roughly into three parts: a supraduodenal portion or proximal third, a retroduodenal por-




A

B

Fig 5.–B.G., a 28 year old white male with chronic cholecystitis but without jaundice or operative indication for common duct exploration. (A) Operative cholangiogram showing an unsuspected calculus in the distal end of the common duct which is slightly dilated and kinked. (B) Operative cholangiogram through T-tube after removal of the calculus. The common duct is normal The pancreatic duct is joined at nearly a right angle by the common duct.

tion which includes the pancreatic segment, and a transduodenal or intramural portion comprising the distal 10 to 14 mm. In 65 to 80 per cent of humans, the pancreatic segment of the common duct extends through the head of the pancreas posterior and medial to the descending duodenum (Baldwin). In about 5 per cent of cases, it is partially invested by pancreas, and in the remainder, it extends in a deep groove in the pancreas.





FIG. 6A.—C.D., a 54 year old white male with a six week history of sharp epigastric pain and a two day history of jaundice. Icteric index 21. A roentgenogram of the abdomen showed gas in the biliary ducts. At surgery, a fistulous communication between the gallbladder and duodenum was found. Postoperative cholangiogram showing dilated common duct with narrowing and angulation of the distal segment. A minor right hepatic radicle dilated and filled with multiple calculi.

The transduodenal portion of the duct tapers from the diameter of the common duct to a diameter of 1 to 2 mm. and averages 1 cm. in length as it traverses the duodenal wall obliquely. According to Westphal, Schondube, and others, it contains the sphincter of Oddi which surrounds the ampulla of Vater and the papilla. The ampulla is surrounded by oblique and longitudinal muscle bundles which blend with the muscle fibers of the duodenal wall and are innervated by the vagus. The papilla is surrounded by a terminal, iris-like ring of circular muscle fibers activated by the sympathetic nerves. Since the ampulla of Vater is formed by the junction of the lumina of the common and pancreatic ducts, it is not

present when the ducts are separated by a septum to their termination at the tip of the papilla, or when they enter the duodenum separately. By common usage in the foregoing instances, the transduodenal portion of the common duct is frequently referred to as the ampulla. When present, the ampulla appears, in most instances, to be a direct continuation of the distal common duct, although Verneuil was of the opinion that the ampulla actually was part of the pancreatic duct.



Fig. 6B.—Postoperative cholangiogram following a second operation four months later, showing a residual calculus in the dilated common duct. Narrowing and angulation of the sphincter are less marked than in the previous examination. The stone-filled right hepatic radicle is not seen. There is air in the hepatic radicles.

Schermer stated that, of 47 cases studied, the pancreatic duct joined the common duct in 11, and the common duct joined the pancreatic duct in 14 instances. The common duct terminates in the papilla of Vater, a small mound-like projection into the duodenal lumen which may be difficult to discern even with the duodenum open.

Pancreatic Duct

Reflux into the pancreatic duct frequently occurs during a cholangiographic examination and familiarity with its anatomy is essential. The pancreatic duct begins in the tail of the pancreas through the convergence of several small radicles. It traverses the gland from left to right near its dorsal superior surface, draining the portion of the pancreas which develops embryologically from the dorsal anlage. At the junction of the superior and caudal portion of the head of the pancreas, the main duct turns sharply in a caudal and posterior direction, and

drains the portion of the gland which develops from the ventral anlage. As the duct approaches the posterior surface of the head of the gland at the level of the papilla of Vater, it turns to the right to join the terminal common bile duct (Figs. 10, 19B, and 20B).

The pancreatic duct may join the common duct proximal to its transduodenal segment, or it may join the common duct to form the ampulla of Vater as a Y. It may parallel the common duct with a joint septum extending to the tip of the papilla, or the two ducts may enter the duodenum separately. The pancreatic duct may be absent, or it may be joined at right angles by the common bile duct prior to its insertion into the duodenum (Fig. 5B).



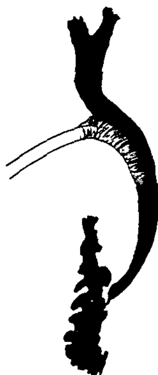


FIG. 7.—C W , a 41 ... ithout jaundice. The cholecystogram ... cholangiogram through a catheter ... lculi measuring up to 7 mm in dian... a long septum

PRESENCE OF SPHINCTERS IN HEPATIC AND PANCREATIC DUCTS

The presence of a sphincter in the common hepatic duct as described by Mirizzi has not been proved conclusively. Schuberth and Sjogren stated that the muscle fibers surrounding the duct are poorly developed and mostly longitudinal. It is their belief that the filling defects may be due to insufficient filling, mucous plugs, and blood clots. There are occasional instances, however, in which during operative cholangiography, a large hepatic radicle that did not visualize on one film will appear suddenly, completely filled, on succeeding films. The intraductal pressure has frequently been observed to increase with succeeding injections. The sudden overcoming of the resistance of a sphincter might explain visualization of

only during a second
been given (Fig. 6A).

Gage has stated that reflux into the pancreatic duct is prevented by thin folds which function as a valve. Cases have been observed in which the pancreatic duct was visualized only on the fourth film, during a series of injections, when the intraductal pressure had reached 40 to 50 cm. of water (Fig. 19B).

VARIATIONS OF NORMAL ANATOMY

The extrahepatic biliary duct system is noted for the great number and diversity of possible variations in the ducts with respect to themselves and their associated blood vessels (Hicken, Coray, and Franz). Variations in the ducts can be studied radiographically, and these are of anatomic interest to the surgeon. If the variations are sufficiently marked, they acquire pathologic significance.



FIG. 8.—S.S., a 27 year old white male with a nine year history of right upper quadrant pain and two attacks of jaundice. There was a two day history of an acute attack associated with upper abdominal spasm and elevated white blood count. The acutely inflamed gallbladder containing two large calculi was removed at operation. The operative cholangiogram shows no calculi in the normal sized common duct. The cystic duct stump crosses over the common duct to a medial insertion. The pancreatic duct is visualized.
(*Surg., Gynec. & Obst.*, 87:299, 1948.)

Variations of the cystic duct insertion into the common duct have considerable practical significance. The cystic duct not infrequently appears to enter the common duct almost at right angles, only to turn and parallel it for a considerable distance before entering it. Consequently, the common duct appears to be dilated, and the cystic duct may be opened under the erroneous impression that it is the common duct. The error is discovered when the surgeon is unable to

drains the portion of the gland which develops from the ventral anlage. As the duct approaches the posterior surface of the head of the gland at the level of the papilla of Vater, it turns to the right to join the terminal common bile duct (Figs. 10, 19B, and 20B).

The pancreatic duct may join the common duct proximal to its transduodenal segment, or it may join the common duct to form the ampulla of Vater as a Y. It may parallel the common duct with a joint septum extending to the tip of the papilla, or the two ducts may enter the duodenum separately. The pancreatic duct may be absent, or it may be joined at right angles by the common bile duct prior to its insertion into the duodenum (Fig. 5B).

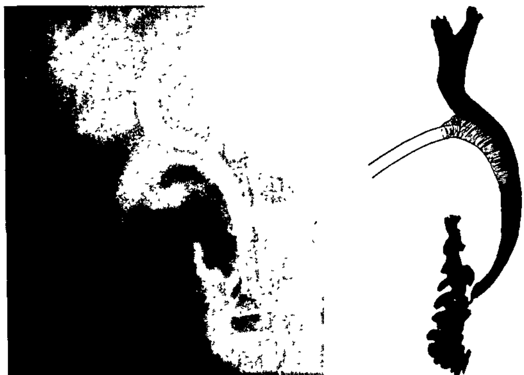


FIG 7 —C W , a 41 year old white male with a two year history of mild pain without jaundice The cholecystogram show cholangiogram through a catheter followi lculi measuring up to 7 mm in diameter a long septum

PRESENCE OF SPHINCTERS IN HEPATIC AND PANCREATIC DUCTS

The presence of a sphincter in the common hepatic duct as described by Mirizzi has not been proved conclusively Schuberth and Sjogren stated that the muscle fibers surrounding the duct are poorly developed and mostly longitudinal It is their belief that the filling defects may be due to insufficient filling, mucous plugs, and blood clots There are occasional instances, however, in which during operative cholangiography, a large hepatic radicle that did not visualize on one film will appear suddenly, completely filled, on succeeding films The intraductal pressure has frequently been observed to increase with succeeding injections The sudden overcoming of the resistance of a sphincter might explain visualization of

The common bile duct varies in length, diameter, and degree of curvature. This is due, in part, to the habitus of the individual. The curvature of the common duct, at times, approaches the configuration of a reverse C, or the common duct may lie in a transverse position. Before considering the passage of sounds or probes into the common duct, the presence or absence of such variations should be determined.

ARTEFACTS AND MISINTERPRETATIONS

There are relatively few artefacts or other causes for misinterpretation in operative cholangiography.

Anatomy Obscured by Radiopaque Objects

If all instruments, including towel clips, are not removed from the operative field, an important segment of the duct system may be completely obscured. This may also be caused by allowing the injection tubing to overlie a portion of the duct. There is usually little difficulty with paracostal incisions in arranging the injection tubing so that it enters from the lateral side. With paramedian incisions, however, it is sometimes difficult to arrange the tubing without kinking it or causing the needle to become dislodged from the duct.

Distortion of Ducts at Injection Site

The cannula, catheter, or needle used for injecting the medium into the common duct almost always produces a slight distortion or angulation of the duct at the injection site. In addition, a localized spasm may be produced by a needle or cannula inserted far enough to touch the opposite common duct wall. This may also follow the insertion of a T-tube. A ureteral catheter inserted too far into the common duct may cause tenting of the wall of the duct.

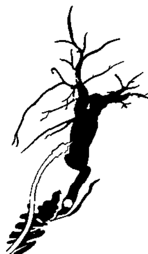
Air Bubbles

Air bubbles are one of the chief causes for difficulty, as they may be misinterpreted as stones. They tend to be spherical and multiple, measuring from 2 to 3 mm. in diameter A study of serial films showed that air bubbles tend to shift their position, but small calculi also may do the same. The presence of air bubbles in the rubber tubing serves as a warning of a possible artefact (Fig. 12B). Constant vigilance is necessary to prevent the entry of air bubbles into the duct system All connections between syringes tubing, and needles must be tight and the tubing free of holes, or any attempt to aspirate bile will draw air into the tubing.

Borders of Bone, Gut, Etc.

The borders of the vertebral bodies or their articular facets may obscure the common duct if the patient is not rotated 5 to 10° to the right. Gas in the intestine can also be confusing, and, sometimes, several such factors combine to produce the erroneous impression of a calculus (Fig. 10).

explore the duct in the direction of the liver. A common septum may be all that divides the ducts for several centimeters, again giving a false impression of the size of the common duct (Fig. 7). The cystic duct may enter the right hepatic duct or may turn and extend behind the common duct for a considerable distance to insert on its medial side (Fig 8). The cystic duct may parallel the



gallbladder containing cholesterol stones was excised and two 1 cm. faceted calculi were removed from the common duct

common duct, entering it well down posterior to the duodenum (Fig 9). If these and similar variations are not detected by means of operative cholangiography, long segments of the cystic duct may be overlooked and remain to serve as a residual source of inflammation, a site for further stone formation, or a cause for common duct obstruction (Fig. 15A).

PATHOLOGY OF THE BILIARY TRACT

The pathologic changes often observed by means of cholangiography include calculi, calcareous debris, narrowing of the transduodenal segment of the common duct, pancreatitis, tumors, strictures, and atresia. As previously mentioned, the gallbladder has not been included in the present study. There is usually fairly



FIG 11A.—D McK., a 46 year old white male with a three year history of duodenal ulcer and an eight week history of severe right upper quadrant pain radiating to the right shoulder The cholecystogram failed to show a gallbladder shadow Gastro-intestinal series revealed a contracted duodenal bulb Icteric index was 16.3 The operative cholangiogram shows multiple calculi in a dilated common duct with dilatation of the major bile ducts

good preoperative evidence, by means of physical examination or cholecystography, of a pathologic gallbladder. Even in patients whose symptoms are due to dysfunction of Lutken's sphincter (collus cysticum), Mallet-Guy has stated that it is more effective to remove the gallbladder than to attempt to preserve it by denervation of the sphincter by vagotomy or splanchnicectomy.

CHOLEDOCHOLITHIASIS

Almost every attempt to visualize the biliary tract radiographically has been motivated originally by the desire to detect common duct calculi. The percentage



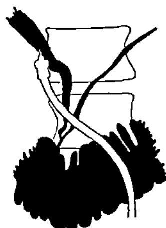


FIG 10.—J V, a 50 year old white male with a 16 year history of indigestion and progressive colicky right upper quadrant pain A cholecystogram failed to reveal a gallbladder shadow The operative cholangiogram shows the normal common duct and a segment of pancreatic duct The injection tubing obscures a portion of the common and pancreatic ducts The common duct was explored through misinterpretation of a calculus-like shadow formed by the edge of the vertebra and duodenum

(*Surg, Gynec & Obst*, 87.299, 1948)

INJECTION MEDIUM

Lipiodol, or any other radiopaque oil, used as the injection medium enhances the probability of artefact and misinterpretation The medium segments and produces bead-like chains of droplets owing to its inability to mix with bile. Because of its high viscosity, it is difficult to inject at a controlled rate. An excessive rate of injection of any medium may produce an artificial spasm of the sphincter of Oddi by suddenly distending the common duct.

INADEQUATE FILLING

A dilated common duct may be inadequately filled with medium. As a result, a portion of the duct system which might contain pathology is not demonstrable This is especially true if lipiodol or any other oil medium is used A series of injections in which at least one film shows an adequate filling of the duct will help to prevent such misinterpretations.

Defects caused by stones vary according to the size and position of the stones in the common duct, as well as to the diameter of the duct. A large stone in contact with the lateral wall of the duct produces a clear-cut hemispherical or U-shaped defect. A stone lodged against the anterior or posterior wall produces a punched out, faceted, or spherical defect. A calculus blocking the lower end of the duct produces a crescentic defect. The proximal common duct eventually be-



FIG 12A.—D.B., a 51 year old white male with a three week history of upper abdominal pain

duct, marked narrowing of the transduodenal segment. The defect in the adjacent duodenal wall is probably due to edema.

comes dilated and may become tortuous (Fig. 11A). The exact number of calculi present is not as important as the demonstration that the common duct is free of calculi. This is determined by T-tube cholangiograms after exploration of the duct. The infrequent common duct calculus that contains a rim of calcium presents no problem. It is seen on the scout film of the abdomen, and its location becomes obvious if the gallbladder visualizes by cholecystography. Even with such a calculus, a cholangiogram is necessary to demonstrate its precise relationship to the duct system (Fig. 12A).

of such calculi which are overlooked by ordinary methods is hard to estimate. As mentioned previously, it probably lies between 10 and 30 per cent of the operated cases.

Biliary calculi, with the exception of those in the gallbladder, are usually nonopaque to roentgen rays. They appear as areas of decreased density with more or less sharply defined borders Calculi may be faceted, irregular, or spherical in outline They may be single or multiple, and may occupy any portion of the

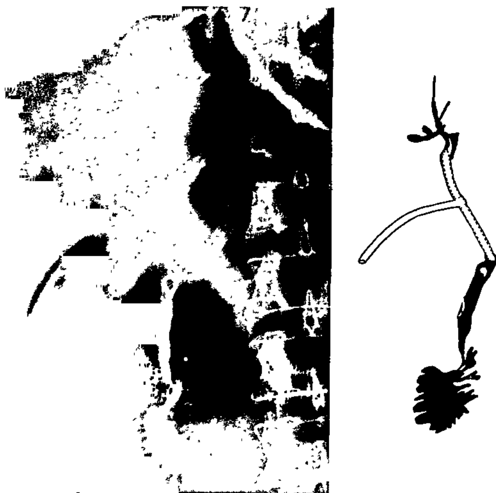


FIG 11B —An operative cholangiogram through the T-tube after removal of calculi shows residual debris in the common duct This was removed before completion of the operation

intrahepatic or extrahepatic duct system. Inasmuch as they tend to overlap, it is difficult to determine their total number. Calculi are often found in the retroduodenal portion of the common duct and in the vicinity of the ampulla of Vater where one of them may become impacted (Fig. 11A). Not infrequently, a major portion of the duct system is filled with calculi of various sizes which seem to have been fitted into place Calculi may also extend into the intrahepatic radicles where they may be inaccessible to exploration (Fig. 6A).

shifts to a study of the terminal portion of the common duct and the sphincter of Oddi. The anatomy and physiology of this region is so complex and controversial that some orientation is necessary before considering its pathology.

Anatomicophysiologic Studies. Westphal regarded the sphincter of Oddi as composed of two parts possessing different functions, structures, and innervations. The proximal portion or antrum, consisting of the ampulla of Vater, was



FIG 13A.—E P, a 61 year old white male with a six month history of recurrent, cramping, right upper quadrant pain associated with transient jaundice. There was steady severe pain for 12 hours prior to admission. Multiple gallstones are seen in the film of the abdomen. An operative cholangiogram showing multiple faceted calculi in the common duct extending into the dilated common hepatic and left hepatic ducts. Y-junction of common and pancreatic ducts

surrounded by oblique and longitudinal muscle fibers and was innervated by the vagus. The distal portion or papilla was surrounded by a circular, iris-like group of muscle fibers under control of the sympathetic nerves. He demonstrated that stimulation of the vagus nerve below the diaphragm with a weak current caused gallbladder contractions, peristaltic movement of the antrum, and relaxation of the papilla. A moderate stimulation of the vagus produced increased gallbladder tone and lively movements of the ampulla so that the gallbladder emptied rapidly

Calculi rarely, if ever, produce a complete obstruction of the common duct. It is almost always possible to demonstrate the medium in the duodenum by operative cholangiography. Frequently, the flow seems scarcely interfered with, in spite of many stones extending up into the hepatic ducts (Fig. 13A). This agrees with the clinical observation of Clute that in 39 per cent of patients with common duct calculi at operation jaundice may never have been present.

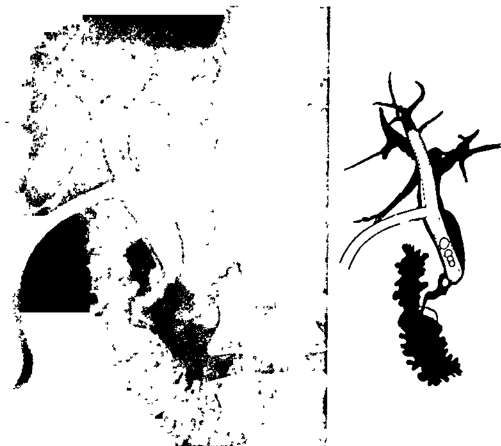


FIG 12B—A postoperative cholangiogram two months after removal of a 1 2 cm. stone from the common duct Narrowing of the transduodenal segment has diminished Note the air bubbles in the T-tube and common duct which should be avoided

Biliary calculi may be formed anywhere in the duct system if the necessary factor of stasis is present The gallbladder, with its normal function of concentrating bile, provides the most frequent site of calculus formation. It is not too uncommon, however, to find one or more good-sized calculi in the common duct, in spite of the presence of a narrow cystic duct or a gallbladder without stones. Calculi may likewise be formed in dilated hepatic radicles where stasis may be due to a narrowed orifice at the junction with the main duct system (Fig. 6A)

DEFORMITIES OF THE TERMINAL COMMON DUCT

Although the initial attempts at biliary tract visualization may begin as a search for calculi, the interest of both the surgeon and the radiologist rapidly

shifts to a study of the terminal portion of the common duct and the sphincter of Oddi. The anatomy and physiology of this region is so complex and controversial that some orientation is necessary before considering its pathology.

Anatomicophysiologic Studies. Westphal regarded the sphincter of Oddi as composed of two parts possessing different functions, structures, and innervations. The proximal portion or antrum, consisting of the ampulla of Vater, was

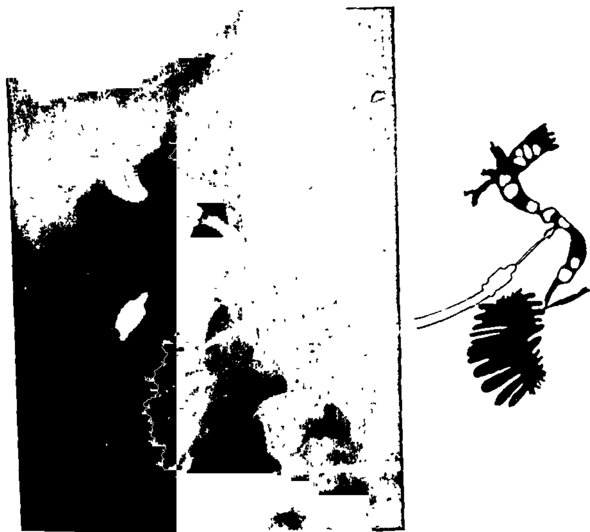


FIG. 13A.—E. P., a 61 year old white male with a six month history of recurrent, cramping, right upper quadrant pain associated with transient jaundice. There was steady severe pain for 12 hours prior to admission. Multiple gal[illegible] operative cholangiogram showing multiple [illegible] the dilated common hepatic and left hepatic [illegible]

surrounded by oblique and longitudinal muscle fibers and was innervated by the vagus. The distal portion or papilla was surrounded by a circular, iris-like group of muscle fibers under control of the sympathetic nerves. He demonstrated that stimulation of the vagus nerve below the diaphragm with a weak current caused gallbladder contractions, peristaltic movement of the antrum, and relaxation of the papilla. A moderate stimulation of the vagus produced increased gallbladder tone and lively movements of the ampulla so that the gallbladder emptied rapidly

(hypermotile dyskinesia). A strong stimulation of the vagus resulted in spasm of the antral sphincter and gallbladder (hypertonic dyskinesia). When the splanchnic nerve was stimulated, the gallbladder and the antral portion of the sphincter relaxed and the papilla contracted (atonic dyskinesia).

Hill stated that the clinical manifestations of hypertonicity associated with rapid gallbladder contractions plus spasm were distention with subsequent pain. Atonicity associated with an atonic gallbladder plus spasm was manifested by a heavy aching sensation.

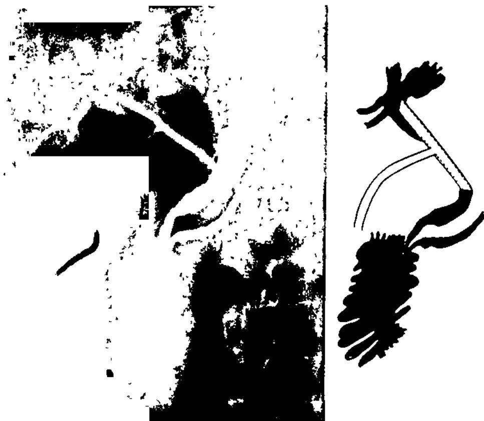


FIG 13B —An operative cholangiogram through the T-tube after removal of 11 calculi by irrigation The ducts are clear of stones.

Mallet-Guy, in an extensive study of the pathology of the biliary tract by means of operative cholangiography and manometry, concluded that the splanchnic nerve was the inhibitor of the biliary duct system, while the vagus nerve increased the tone of the gallbladder, common duct, and the sphincter of Oddi. He treated *hypertonie* of the sphincter by vagotomy either at the angulus of the stomach or subdiaphragmatically with good results in a relatively small number of cases followed up to two years. He treated a considerably larger group of cases of *hypotonie* of the bile ducts by a unilateral splanchnicectomy with 90 per cent good results followed up to six years.

Negri studied the region of the sphincter of Oddi by serial postoperative cholangiograms and by histologic sections taken from cadavers. He demon-

strated that a great diversity of normal radiologic images of the terminal common duct and sphincter was possible, depending on normal anatomic variations at the level of the ampulla of Vater. Longitudinal and oblique muscle fibers were described surrounding the ampulla of Vater, as well as circular muscle fibers surrounding the papilla. In addition, he noted circular fibers around the terminal common duct, semicircular fibers around the pancreatic duct, and, at times, circular fibers embracing them both to form a common sphincter. Variations of this anatomic arrangement accounted for such findings as regurgitation of contrast media into Wirsung's duct as a normal and physiologic phenomenon without postulating functional abnormalities.

Terminology. It is obvious that with such a variable and complex anatomic and physiologic relationship, interpretation of deformities in the region of the sphincter of Oddi must be made with caution. Suarez, according to Tabbal, indicated that it was impossible to study adequately the physiology and physiopathology of the biliary passages by means of two or three radiographs taken during an operative act with the abdomen open, and with the patient under the effects of transitory anesthesia or different drugs. Interpretation frequently must be made in the light of the subsequent course of the individual case.

Also obvious is the fact that it is misleading to employ terminology which already is confused by such terms as "spastic cholepathy" (Schmieden and Niessen), "biliary dyskinesia" (Ivy), "dyssynergia of the common duct" (Best and Hicken), "papillitis, sphincteritis" (Walters), "scleroretractile choledocho-odditis" (Del Valle), and "odditis" (Mirizzi). To simplify the existing terminology of the transduodenal segment, an effort has been made to choose descriptive terms for the pathologic changes observed. These include narrowing due to transitory spasm, prolonged spasm, hypertrophy, inflammation, and fibrosis.

Narrowing of the Transduodenal Segment of the Common Duct

Transitory Spasm. Transitory spasm of the sphincter of Oddi is a physiologic reaction of the normal sphincter to an excessively rapid injection of contrast medium or to the use of a medium whose temperature varies too widely from body temperature. The associated cholangiographic deformity in the region of the sphincter of Oddi consists of either an abrupt narrowing or, less often, of a complete block with the common duct ending in a sharp taper The narrowing may be filiform or tapered, and usually involves the entire transduodenal portion of the common duct. Spasm of this type is generally no longer apparent on serial films, and there is no associated dilatation of the biliary ducts.

Transitory spasm of the sphincter of Oddi is also seen when the sphincter is hyperirritable, a condition that has been observed in the presence of infected bile (Figs 29A and B). The injection of as little as 5 cc. of saline into the common duct during a 40 second interval has been sufficient to produce spasm of such a sphincter which permitted no medium to enter the duodenum in spite of an intraductal pressure of 60 cm. of water A possible mechanism for such a spasm might be inflammation of the mucosa and submucosa due to infected bile.

Transitory spasm of the sphincter of Oddi also occurs in patients with psychogenic disturbances (Fig 14B). This spasm is accompanied by true biliary colic and is frequently associated with subjective symptoms of pylorospasm. Pavel,

according to Colp, stated that sphincter spasm associated with emotional excitement may even cause jaundice.

Transitory spasm due to increased irritability of the sphincter of Oddi without dilatation of the common duct may be precipitated by a small dose of morphine administered intravenously. Colp advocated this as a therapeutic test for "dyskinesia." If the pancreatic duct enters the common duct proximal to their common sphincter, the administration of secretin prior to morphine greatly amplifies the severity of the resulting colic. A flow of 80 or 90 cc. of pancreatic juice reaching

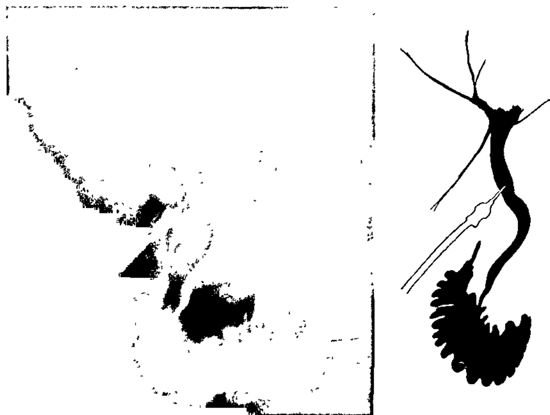


FIG 14A.—S H, a 29 year old white male with a history of recurrent sharp epigastric and periumbilical pain associated with nausea and vomiting Cholecystectomy for acute cholecystitis 16 months previously There was considerable emotional disturbance. Morphine reproduced a typical attack of pain Laparotomy disclosed the absence of the gallbladder and a normal common duct An operative cholangiogram shows a normal common duct

the duodenum within the first 20 minute period after injection may be reduced to 8 or 10 cc. with a consequent marked increase in intraductal pressure and subsequent pain The cholangiographic deformity of the sphincter of Oddi following the injection of morphine is similar to that which is seen following an excessively rapid injection of contrast medium

Transitory spasm may be resolved by the use of various nitrites, with the simultaneous relief of pain. Intravenous aminophylline and papaverine have proved to be relatively effective These drugs may have to be repeated, however, if colic recurs.

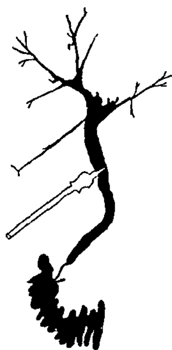
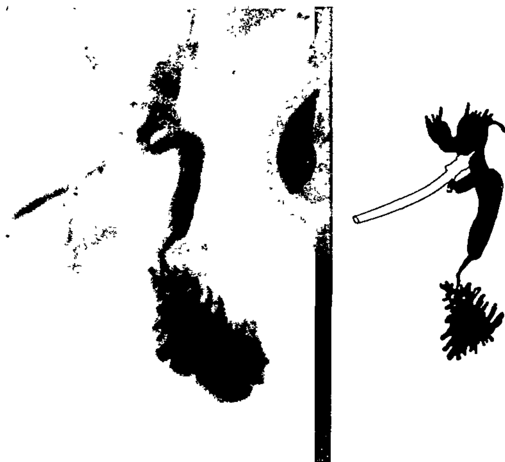


Fig 14B – An operative cholangiogram 15 minutes after the intravenous administration of morphine shows spasm of the transduodenal segment of the common duct.

Prolonged Spasm. Prolonged spasm of the sphincter of Oddi is always associated with proximal dilatation of the biliary system and with some degree of stagnation of bile. This spasm may be associated with biliary colic and jaundice It may occur in the absence of common duct calculi, and even when stones are present, complete occlusion of the duct is rare.



of three months' duration and jaundice for three days Laboratory findings were consistent with obstructive jaundice An operative cholangiogram shows a marked narrowing and irregularity in the region of the sphincter of Oddi with moderate dilatation of the proximal common and hepatic ducts, and the residual dilated cystic duct stump with medial insertion No calculus is present.

Prolonged spasm is frequently associated with an active duodenal ulcer. Archibald, in 1919, demonstrated that painting the papilla with hydrochloric acid produced a spasm able to withstand a pressure of 80 cm of water. Doubilet and Colp produced a spasm by introducing 0 9 per cent hydrochloric acid through a duodenal tube and recorded T-tube common duct pressures as high as 25 5 cm of water Obstructive jaundice following cholecystectomy has been observed to dis-

appear on several occasions following intensive medical treatment of an active duodenal ulcer (Figs. 15A, B, and C).

Prolonged spasm of the sphincter may also be associated with chronic cholecystitis or chronic inflammation in a long remnant of the cystic duct. Giordano and Mann and others have postulated a reflex mechanism as the cause for such spasm. Correction of obvious bile duct pathology frequently relieves sphincter spasm without a direct attack on the sphincter. Colp suggested that a similar reflex mechanism might also play a role in jaundice associated with acute cholecystitis



FIG 15B.—An operative cholangiogram through a double lumen T-tube following common duct exploration shows little change in the narrowing in the region of the sphincter.

when the common duct is free of calculi Extension of the acute inflammation rarely involves the region of the sphincter directly, even when there is considerable edema of the tissues overlying the supraduodenal portion of the common duct

Prolonged spasm probably plays an important role in the production of jaundice associated with common duct calculi. Complete obstruction of the common duct by calculi is rare, and frequently numerous stones hardly seem to interfere with the flow of bile into the duodenum. Jaundice may appear when spasm of the

sphincter of Oddi occurs as a result of irritation arising from a stone in the ampulla of Vater. Decrease or disappearance of jaundice occurs in many cases in which subsequent exploration or cholangiogram discloses a calculus in the ampulla which is much too large to pass. In such cases, the disappearance of jaundice is probably due to diminution of spasm of the sphincter rather than to passage of a stone.

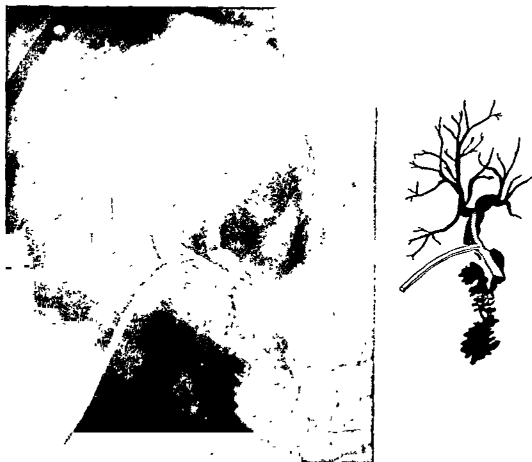


FIG. 15C.—Postoperative cholangiogram six weeks later, showing a normal common duct. The narrowing of the sphincter and the proximal dilatation have disappeared.

Hypertrophy Hypertrophy of the sphincter of Oddi is the result of prolonged or repeated episodes of spasm. The wall of the transduodenal segment is considerably thickened, with a narrowing of its lumen, owing to a hypertrophy of the smooth muscle fibers of the sphincter. The clinical picture caused by hypertrophy is similar to or an accentuation of that which is seen with prolonged spasm. Duodenal ulcer probably plays the predominant role in the production of this lesion. Giordano and Mann reported a case with an excellent illustration of hypertrophy of the muscle fibers of the sphincter associated with duodenal ulcer.

Inflammation. Inflammation of the sphincter of Oddi usually occurs as a result of a neighboring inflammatory process. This may be associated with gallstones in the terminal common duct and infected bile. The inflammatory process may cause

the adjacent duodenal mucosa to become edematous, producing a filling defect of the duodenum (Fig. 12A). Inflammation of the sphincter may result from an adjacent area of pancreatitis (Fig. 18B) It is difficult to be certain of inflammation of the sphincter in the absence of such evidence as edema or surrounding pan-



Fig 16A—C J, a 43 year old white male, a chronic alcoholic, with a three week history of sharp epigastric and right upper quadrant pain radiating to the back [illegible] er, [illegible] ne [illegible] nd [illegible] of the pancreas An operative cholangiogram through a T-tube [illegible] shows marked narrowing and displacement of the pancreatic segment of the common duct. There is persistent narrowing of the transduodenal segment The proximal common duct and hepatic branches are slightly dilated Note the calcareous deposits in the head of the pancreas and the insertion of the common ducts into the transverse duodenum.

creatitis. It is possible, however, to demonstrate the role of spasm in conjunction with inflammation by repeating cholangiographic studies 10 to 12 *minutes after* administration of the intravenous aminophylline. Mallet-Guy obtained this information by injecting procaine into the gastrohepatic omentum at the angulus of the stomach, a procedure with which we have had no experience. It is probable

that spasm maintained by inflammation of the sphincter plays an important role in the resulting deformity. Common duct drainage may have to be prolonged for several months following correction of the local pathology before the region of the sphincter regains a normal cholangiographic appearance.

Fibrosis. Fibrosis of the sphincter of Oddi is due to chronic and repeated episodes of inflammation. The wall of the transduodenal segment is thickened, with narrowing of its lumen, owing to a replacement of the smooth muscle of the sphincter with fibrous connective tissue. There is dilatation of the proximal biliary



FIG. 16B—A postoperative cholangiogram after two weeks of common duct drainage shows no change.

ducts. In the presence of fibrosis, the use of antispasmodics and prolonged common duct drainage are of no avail in relieving the obstruction. The deformity persists and has been seen in postmortem cholangiograms confirmed by histologic sections (Fig 21B).

The differentiation of a narrowing due to prolonged spasm from one due to hypertrophy, inflammation, or fibrosis is impossible at the initial cholangiographic observation. The dividing lines are somewhat arbitrary, and several of these entities may be present simultaneously. Only by following the course of the patho-

an apprecia-

Pancreatitis

Cholangiographic manifestations of pancreatitis depend on the location of the inflammatory process within the head of the pancreas and on the resulting de-

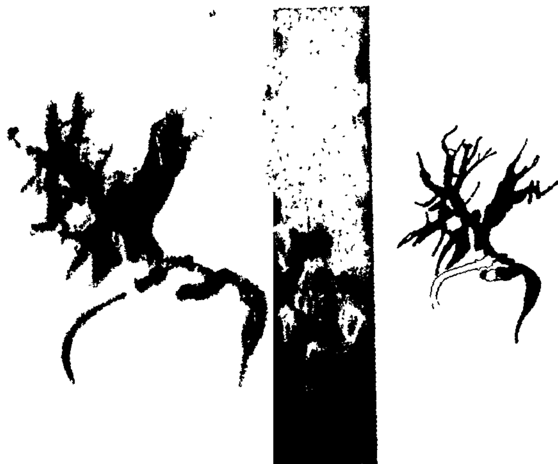


Fig. 17A.—F.M., a 50 year ... on associated with cramping right upper ... d a four day history of jaundice Laborat... The patient was thought to have a neoplasm in the region of the ampulla of Vater or head of the pancreas. An operative cholangiogram shows dilatation of all the bile ducts with a large calculus in the dilated cystic duct The pancreatic segment of the common duct is narrowed by extrinsic pressure with complete block in the region of the ampulla of Vater Transduodenal exploration of the ampulla with biopsy failed to reveal tumor Dilated cystic duct anastomosed to duodenum

formity of the pancreatic portion of the common bile duct. Disease limited to the body or tail of the pancreas produces no demonstrable change in a cholangiogram This is true both for acute hemorrhagic and chronic pancreatitis. Normal operative cholangiograms were observed in 3 patients with acute hemorrhagic pancreatitis who were operated on with diagnoses of intestinal obstruction and ruptured peptic ulcer.

When the head of the pancreas is inflamed, the characteristic cholangiographic

deformity of the pancreatic segment of the common duct is likely to be present. This deformity depends on the course of the duct through the head of the pancreas, which results in its smooth, concentric narrowing (Figs. 16A and B). If the duct lies in a deep groove on the posterior surface of the pancreas, inflammation in this region produces a smooth, eccentric narrowing of the involved portion of the duct. Either type of narrowing may progress to complete obstruction of the common duct (Fig 17A). The proximal biliary duct system is dilated, and there may or may not be an associated inflammatory narrowing of the transduodenal segment. There is often an abrupt angulation of the common



FIG 17B —A postoperative cholangiogram shows the common duct almost normal after four weeks. The anastomosis between the cystic duct and the duodenum is closing.

duct proximal to its pancreatic segment, at times exceeding a right angle Calculi, when present, are proximal to the narrowed, kinked portion of the common duct rather than in the more usual location in the ampulla of Vater (Figs. 18A and B).

The significance of visualization of the pancreatic duct during cholangiography has been discussed by many authors Levens found reflux present in 21 to 23 per cent of his cases The reflux was not always constant in the same patient. In 16 cases, it was attributed to spasm of the sphincter of Oddi, in 3 to stones, and in 2 to stricture. Doubilet reported reflux in 20 per cent of his patients and attributed it to spasm. Mirizzi also was of the opinion that it was due to spasm and might

Fig. 18A—P.S., a 34 year old white male with a three year history of recurrent jaundice and mild transitory right upper quadrant pain
which had been diagnosed as infectious hepatitis on two previous hospital admissions. The cholecystogram revealed a functioning gall-
bladder with possible nonopaque calculi. The liver chemistry was consistent with obstructive jaundice. An operative cholangiogram
shows narrowing and displacement of the pancreatic segment of the common duct. Small calculi are present in the supraduodenal seg-
ment with proximal dilatation of the biliary tract.

cause pancreatitis. He believed that a dilated, sinuous pancreatic duct seen throughout its entire length, with visualization of secondary branches was evidence of such pancreatic inflammation. Robins and Hermanson found reflux in 4 out of 25 cases, all 4 of which had chronic pancreatitis as evidenced by enlargement and hardening of the gland. On the basis of these findings, they considered reflux diagnostic of pancreatitis. Hunt, Hicken, and Best found reflux in 5 out of 56 cases, with induration of the pancreas in only one of them. They considered



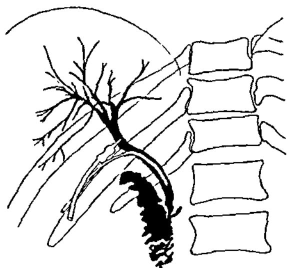


FIG 18B—A postoperative cholangiogram four and one-half months after removal of the calculi shows one arm of the T-tube eroded into the duodenum There are multiple stones in the common duct with further narrowing and angulation of the pancreatic segment of the common duct There is calcification of the head of the pancreas

that filling of the pancreatic duct indicated close relationship between the openings of the pancreatic and common ducts with more than usual pressure in the ampulla Because filling of the pancreatic duct was occasionally followed by transient pancreatitis, they felt that reflux was an indication for common duct drainage. Mallet-Guy stated that he had observed a marked or limited reflux into the pancreatic duct in the majority of 29 cases of coexistent chronic pancreatitis and *hypertonic* of the sphincter of Oddi.

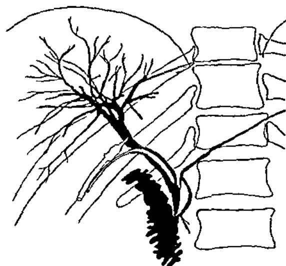
Reflux into the pancreatic duct was observed in 30 per cent of the present





A





B

FIG. 19 – C E, a 52 year old white male with a 10 year history of right upper quadrant pain induced by fatty foods and an acute attack of three weeks' duration without jaundice. A tender mass 3 cm in diameter was present below the right costal margin The cholecystogram revealed

d duodenal bulb. A

) An operative chol-

r intrahepatic radicles

m. The common duct

s

n

series of 150 cases It was usually confined to the distal 4 or 5 cm. of the duct and was not always constant in the same patient, sometimes being demonstrable in one examination and not in a second. It was seen most frequently on the third film of a series after the total amount of the medium had been injected, and the intra-





FIG 20A—M H, a 33 year old white male with a history of cholecystectomy for gallstones two years before admission and a splenectomy for congenital hemolytic icterus one year later Jaundice cleared following splenectomy, but epigastric and left upper abdominal pain which radiated to the back recurred Blood amylase studies were persistently elevated Clinical symptoms were reproduced by 1/6 gram of morphine intravenously. Laparotomy disclosed a slight enlargement of the common duct which contained calculi. An operative cholangiogram shows multiple calculi in a dilated common duct There is almost complete visualization of the sinuous pancreatic duct and its branches Note the tortuous cystic duct stump overlying the dilated common hepatic duct

ductal pressure was at a maximum. In some cases, even the fine tributaries of the pancreatic duct were visualized without using injection pressures over 20 cm of water.

Out of 10 cases diagnosed as pancreatitis either on the basis of operative findings or elevated serum amylase, the pancreatic duct was *visualized in only 2*. In

one of these, the pancreatic duct was sinuous and visible throughout its entire length (Figs. 20A and B). In 3 cases the inflammation was confined to the body and tail of the pancreas, and the common duct was normal by cholangiography. A postmortem cholangiogram in another case of pancreatitis failed to reveal the pancreatic duct. Injection of the medium into the proximal pancreatic duct showed that it was dilated and separated from the common duct by a septum (Figs. 21A and B).



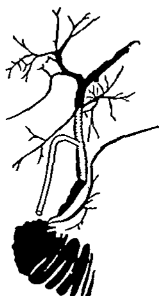


FIG. 20B—An operative cholangiogram through a T-tube after removal of the calculi. The duct is clear of calculi

Reflux depends primarily on the anatomic arrangement, with the junction of the pancreatic and common ducts occurring proximal to the papillary portion of the sphincter of Oddi. Reflux is more likely to occur when there is spasm of this portion of the sphincter with an increase in intraductal pressure as in some cases there is a valve-like mechanism at the mouth of the pancreatic duct which permits reflux into the pancreatic duct only at pressures of 40 to 50 cm. of water (Figs. 19A and B). On the basis of our experience, reflux of opaque media into the duct of Wirsung does not warrant the diagnosis of pancreatitis per se.

NEOPLASMS

Neoplasms may involve any portion of the intrahepatic or extrahepatic bile ducts including the liver parenchyma. Liver neoplasms, either primary or meta-

static, are apparent as space-occupying lesions inasmuch as they displace and distort the hepatic radicles They must be differentiated clinically from liver abscesses, cysts, and gummas.

Carcinomas involving the bile ducts and head of the pancreas produce persistent, complete occlusions with funnel-shaped or irregular defects. There is marked dilatation and blunting of the proximal intrahepatic radicles (Figs. 22 and 23). A duct lesion in the portal fissure or in the liver may mislead the



FIG 21A–G A, a 58 year old white male with a two week history of right shoulder and back pain and an old history of pulmonary emphysema with cor pulmonale The patient was semicomatose but in obviously severe generalized abdominal pain until death on the sixth hospital day A postmortem cholangiogram shows narrowing of the terminal common duct with a small circular defect.

surgeon operating without the benefit of cholangiography. Concluding that he has explored a patient with hepatitis, he usually has terminated the operation without definite surgery Mallet-Guy stated that an early carcinoma of the head of the pancreas which had not completely blocked the common duct could be diagnosed by cholangiography, but that the differential diagnosis should include chronic pancreatitis The pressure deformity might be eccentric, similar to that which is seen in pancreatitis Such early carcinomas have not yet produced jaundice and are usually incidental findings.

The common or common hepatic ducts may also be invaded, compressed, or completely blocked by pressure due to metastatic lymph nodes, metastatic carcinoma of the pancreas or stomach, or retroperitoneal sarcomas.



Fig. 21B.—A postmortem cholangiogram following injection of the pancreatic duct shows narrowing of the distal pancreatic duct with proximal dilatation. A common septum is present between the ducts extending to the tip of the papilla. Necropsy revealed a recent myocardial infarct and acute pancreatitis. Narrowing of the transduodenal segment of the common duct is due to fibrosis. The circular defect in the distal common duct is caused by glandular proliferation in the mucosa.

Choledochitis

Choledochitis, a rare inflammatory lesion of the common and hepatic ducts, presents the cholangiographic picture of a generalized narrowing of the lumen of the ducts with rigidity and thickening of their walls. Intermittent jaundice for a prolonged period, even in the absence of calculi, is frequently associated with this condition. A chronic infection of the large glands in the walls of the duct gives rise to a low grade cholangitis and has been advanced as the etiologic agent (Burden, quoted by Macdonald). French surgeons described this entity as a "pipestem duct" in which the common duct scarcely admits a probe (Colp). Whipple reported 3 cases in which reoperation for jaundice following cholecystectomy disclosed only fibrous connective tissue left in place of the common and hepatic ducts between the duodenum and portal fissure. He was certain that the

FIG 22A —H H, a 42 year old colored male with a three week history of fatigue, aching abdominal pain, and a three day history of jaundice. The cholecystogram revealed nonvisualization of the gallbladder Laboratory studies were consistent with obstructive jaundice. An operative cholangiogram shows the dilated biliary duct system with a complete block in the region of the ampulla

(*Surg, Gynec & Obst*, 87.299, 1948)



FIG 22B —An operative specimen opened, showing block of the common duct by a carcinoma in the vicinity of the ampulla

(*Surg, Gynec & Obst*, 87.299, 1948)

common duct had not been injured at the time of cholecystectomy and explained the findings on the basis of a reflux of activated pancreatic juice.

When choledochitis is found at reoperation following cholecystectomy, considerable confusion may occur if cholangiography is not utilized. The common duct appears markedly dilated, but this is actually due to an inflammatory thickening of the walls. This explains the rigidity of the walls and the narrowing of the lumen which fails to dilate in spite of high injection pressures. Many months of T-tube drainage may be necessary before such a duct returns to a relatively normal state (Figs. 24A, B, and C).



FIG 23 – F E, a 54 year old white male with a two month history of dull umbilical pain radiating to the flanks and back associated with a 20 pound weight loss and jaundice of one week's duration An ill defined hard mass was palpated in the right upper abdomen. A cholecystogram revealed nonvisualization of the gallbladder shadow A gastro-intestinal series revealed a widening of the C loop of the duodenum Laboratory findings were suggestive of obstructive jaundice, and the stools contained blood Laparotomy disclosed an inoperable carcinoma of the pancreas with metastases The patient died of gastro-intestinal hemorrhage 10 days postoperatively A postmortem cholangiogram shows complete obstruction of the common duct with marked proximal dilatation of the biliary ducts

STENOSIS

Postoperative cicatricial stenosis of the hepatic and common bile ducts occurs occasionally. According to Cattell and Walters, however, it comprises 80 and 90 per cent, respectively, of all common duct stenosis The lesion is most often at the junction of the cystic and common ducts Cholangiography reveals a smooth, concentric narrowing of the duct with proximal dilatation if the stenosis is suffi-

[illegible]

[illegible] in atresia at the site of anastomosis. With atresia, there is a marked

proximal dilatation of the duct system which returns to normal following corrective surgery (Figs. 26A and B).



FIG 24A.—E W., a 31 year old white male with a 12 year history of recurring episodes of ... ck in the Army was diagnosed as ... stones, was removed in the Army ... ne back. There was jaundice constantly for six months prior to admission Liver function and fragility tests were normal At operation, the common duct appeared to be 2 cm in diameter An operative cholangiogram with a catheter in the common duct shows a short segment of the narrowed common duct. Angulation and narrowing of the transduodenal segment were also present.

(*Surg, Gynec & Obst*, 87·299, 1948)

CONGENITAL ATRESIA

Congenital atresia of the bile ducts, while rare, does occur with sufficient frequency to make efforts at surgical correction worth while. Hicken and Crellin were able to collect 200 cases from the literature and added 5 of their own. Ladd and Gross stated that in 16 to 20 per cent of the cases the stenosis was low enough in the hepatic or common duct to provide sufficient proximal duct for anastomosis to the duodenum or jejunum. Cholangiographic evidence of the

patency of the ducts is a definite improvement over the former method of trying to distend the ducts with saline injected through the gallbladder (Hicken and Crellin). The opaque media may be injected into the gallbladder or any structure in the portal fissure which contains bile. In certain cases, the media can also be injected by liver puncture, a method Mirizzi has employed with neoplastic stenosis of the main bile duct.



FIG. 24B.—Operative cholangiogram with a catheter in the common duct shows a normal proximal biliary duct system
(*Surg., Gynec. & Obst.*, 87 299, 1948.)

MISCELLANEOUS

Other less frequent pathologic conditions of the bile ducts are demonstrable by operative cholangiography. Mallet-Guy described intermittent obstruction of the common duct by both hydatid cysts and ascaris. Urrutia and Ferraris reported 2 cases of flukes in the hepatic and common ducts. Mirizzi described a perivaterion diverticula and pseudocystic dilatation of the common duct, both conditions commonly associated with icterus. Thin-walled varicose veins may obscure the

proximal dilatation of the duct system which returns to normal following corrective surgery (Figs. 26A and B).



Fig. 24A.—E. W., a 31 year old white male with a 12 year history of recurring episodes of painless jaundice lasting approximately one week. One attack in the Army was diagnosed as infectious hepatitis. The gallbladder, said to have contained stones, was removed in the Army following a severe attack of abdominal pain radiating to the back. There was jaundice constantly for six months prior to admission. Liver function and fragility tests were normal. At operation, the common duct appeared to be 2 cm. in diameter. An operative cholangiogram with a catheter in the common duct shows a short segment of the narrowed common duct. Angulation and narrowing of the transduodenal segment were also present.

(*Surg., Gynec. & Obst.*, 87:299, 1948.)

Congenital Atresia

Congenital atresia of the bile ducts, while rare, does occur with sufficient frequency to make efforts at surgical correction worth while. Hicken and Crellin were able to collect 200 cases from the literature and added 5 of their own. Ladd and Gross stated that in 16 to 20 per cent of the cases the stenosis was low enough in the hepatic or common duct to provide sufficient proximal duct for anastomosis to the duodenum or jejunum. Cholangiographic evidence of the

ography was too complex and time-consuming. His method consisted of a slow injection of 20 cc. of water into the gallbladder or a rapid injection of a few cubic centimeters of water into the common duct by means of a special curved cannula lying in the cystic duct. The resulting pressure rise and its subsequent fall were



Fig. 25 –M.W., a 44 year old white female with a history of persistent indigestion and right upper quadrant pain following cholecystectomy 18 months previously The same symptoms persisted with jaundice. An operative cholangiogram shows the stump of the cystic duct and the common duct without calculus or obstruction, there is a definite narrowing of the common duct distal to the entrance of the cystic duct with minimal proximal dilatation (arrow), passage of a No. 12 French catheter was easily accomplished, exploration was negative

recorded on a kymograph, the drum of which made a complete revolution in 25 seconds. As a result of his experience in approximately 850 cases up to 1948, Mallet-Guy was able to add much useful information to his cholangiographic studies.

common duct in portal hypertension associated with cirrhosis. Serious hemorrhage may result from a duct exploration deemed necessary because of a history of jaundice A cholangiogram with the medium injected through the cystic duct is likely to reveal a tortuous or kinked duct with extrinsic pressure defects caused by the varicosities (Fig. 27).

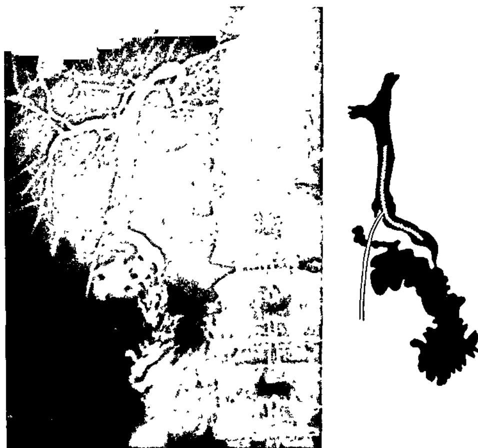


FIG 24C—A postoperative cholangiogram after 10 months of T-tube drainage, demonstrating reduction of the narrowing and angulation of the transduodenal segment Forty cm of water pressure through the T-tube produced discomfort and 50 cm caused pain. Nitroglycerin and atropine had no effect on the duct pressure or cholangiogram.

MANOMETRY DURING OPERATIVE CHOLANGIOGRAPHY

INTRODUCTION

The addition of manometry to operative cholangiography was motivated by a desire to minimize the errors inherent in a method which relied on brief glimpses of a changing common duct picture. Since fluoroscopy in the operating room was not practicable, intraductal pressure measurements were made to obtain additional information Bergeret and Caroli, in 1941, introduced "radiomanometrie," which consisted of simultaneous measurements of the intraductal pressure during operative cholangiography.

Mallet-Guy, in 1942, introduced a modification of manometry associated with cholangiography, for he believed that the recording of pressure during cholangi-

ducing the known values for a system filled with water at body temperature, the formula becomes: $70.4 = \frac{1}{4}\,h. \times 0.991 \times 980 \times r$. The error when a tube with a diameter of 1.5 mm. is used equals 1.9 cm., and for a diameter of 2.5 mm. is only 1.15 cm. Since the changes in bile duct pressure may be of the order of 40 or 50 cm., the error even with tubes 1.5 mm. in diameter is not critical and correction may be made for it.



Fig. 26B.—Postoperative cholangiogram made following anastomosis of the common duct to the Roux loop of the jejunum, with relief of obstruction.

Equipment. In addition to the equipment used in operative cholangiography, a spinal fluid manometer with a three-way stopcock and a 30 cc. syringe is required (Fig. 28). Kymographic recording is preferable if the necessary recording equipment is available. A No. 6 whistle-tip ureteral catheter with an adapter is the most satisfactory type of connection to the duct system when inserted through a small transverse incision in the cystic duct. Multiple holes in the end of the catheter and its plasticity insure an adequate mechanical system. Metal cannulae tend to kink the cystic duct and do not record properly unless held in position manually.

Operative Technic. After the same preparation as in operative cholangiography with the dissection of the junction of the cystic and common ducts, a small

Lacking the necessary equipment and experience for a manometric study as performed by Mallet-Guy, we have been recording common duct pressures during operative cholangiography by means of a spinal manometer, in an effort to evaluate the additional information obtained.



FIG 26A—A B, a 57 year old white male with a 20 month history of common duct injury during cholecystectomy. Secondary anastomosis of the common duct to the duodenum was followed by atresia and cholangitis. An operative cholangiogram shows complete obstruction of the common duct with marked dilatation of the proximal biliary ducts

TECHNIC

Physical Principles. In recording an accurate pressure in any system where a simultaneous flow is occurring, a separate connection of a manometer to the system is required If a Y-tube is used to connect the manometer to the tube through which the flow is occurring, the resulting pressure reading will be a composite of pressure and rate of flow, becoming more inaccurate at more rapid rates of flow.

Mallet-Guy stated that the internal diameter of the cannula or trocar used to connect the biliary duct system to the manometer has been fixed experimentally at 2 5 mm. In his opinion, when smaller cannulae are used, the capillary action produces false readings

Errors due to capillary action occur at the fluid gas interphase and are not dependent on the size of the fluid filled parts of the system. The error due to capillary action in tubes of small diameter is calculated according to the formula: $\gamma = \frac{1}{2}$ h d g r, γ = surface tension in dynes per sq. cm.; h = height of liquid in the capillary tube; d = density of the liquid; g = gravitational constant expressed in cm. per second squared, and r = radius of the capillary tube. Intro-

ducing the known values for a system filled with water at body temperature, the formula becomes: $70.4 = \frac{1}{2}$ h. $\times$ 0.994 $\times$ 980 $\times$ r. The error when a tube with a diameter of 1.5 mm. is used equals 1.9 cm., and for a diameter of 2.5 mm. is only 1.15 cm. Since the changes in bile duct pressure may be of the order of 40 or 50 cm., the error even with tubes 1.5 mm. in diameter is not critical and correction may be made for it.





FIG 26B.—Postoperative cholangiogram made following anastomosis of the common duct to the Roux loop of the jejunum, with relief of obstruction.

Equipment. In addition to the equipment used in operative cholangiography, a spinal fluid manometer with a three-way stopcock and a 30 cc syringe is required (Fig. 28). Kymographic recording is preferable if the necessary recording equipment is available. A No 6 whistle-tip ureteral catheter with an adapter is the most satisfactory type of connection to the duct system when inserted through a small transverse incision in the cystic duct. Multiple holes in the end of the catheter and its plasticity insure an adequate mechanical system. Metal cannulae tend to kink the cystic duct and do not record properly unless held in position manually.

Operative Technic. After the same preparation as in operative cholangiography with the dissection of the junction of the cystic and common ducts, a small





Fig 27 — W M , a 60 year old jaundiced white male with a history of a perforated gallbladder 60 days before admission. Laboratory examinations were consistent with hepatitis and posterior myocardial infarction At operation, the common duct was obscured by large varicose veins An operative cholangiogram shows a kinked common duct with narrowing at the distal end and minimal dilatation of the hepatic radicles, no calculus

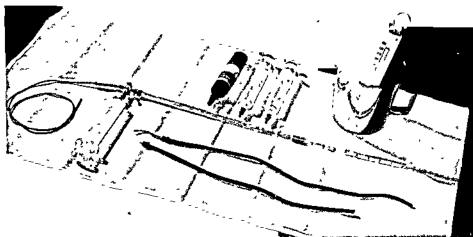


Fig. 28 — Equipment necessary for operative cholangiography and manometry

transverse incision is made in the cystic duct within 1 cm. of this junction. A culture of the bile is taken. A No. 6 ureteral catheter, connected to a spinal manometer and a 30 cc. syringe by means of a three-way stopcock and adapter, *is filled with saline from the syringe. The manometer is likewise filled with saline,* care being taken to eliminate air bubbles in the system. The ureteral catheter is then inserted through the incision in the cystic duct approximately 2 or 3 cm. and
sionally *some difficulty will be experienced in*
leister's valves. If gentle manipulation does not
disclose the correct passage, the catheter should be reinserted through another small transverse incision nearer the common duct.

A No. 22 needle attached by amber rubber tubing to a saline syringe is inserted through the anterior wall of the common duct, as described for operative cholangiography The zero point of the manometer is adjusted to the level of the common duct, and the manometer is put in communication with the duct system by turning the stopcock. The level of saline in the manometer is allowed to fall until it is balanced by intraductal pressure. This is the "initial pressure" or the measure of the resistance of the sphincter of Oddi. Small fluctuations in pressure are present with respirations if the mechanical system is adequate.

Five cc. of saline warmed to 98° F. are injected through the needle, with an injection time of 30 to 40 seconds recorded by a stopwatch. The pressure at the beginning and end of the injection is recorded Three injections of 5 cc. each of 70 per cent diodrast or 75 per cent neo-iopax are then made, with each injection being followed by roentgen ray exposure. The pressure is recorded, likewise, at the beginning and end of each injection. If there is any doubt concerning the technical adequacy of the films, the ureteral catheter may be left in place while the gallbladder is removed If after the wet films are seen, it becomes necessary to repeat the cholangiography, this may be done readily by injecting contrast media through the catheter in the cystic duct

Factors Influencing Common Duct Pressure

After the gallbladder has been removed from communication with the rest of the extrabiliary duct system by occlusion of the cystic duct, common duct pressures depend almost entirely on the state of contraction of the sphincter of Oddi. Elasticity of the walls of the ducts plays a relatively minor and passive role Even when there has been overdistention of the ducts because of obstruction, once the system is filled to capacity, pressure changes depend on the sphincter of Oddi.

Many investigators have reported on the normal pressure in the extrabiliary duct system both in animals and in humans In animals without a gallbladder, there is no papilla for the entrance of bile into the duodenum and no sphincter of Oddi. Bile flows constantly and cannot be arrested by irritating the orifice through which it enters the gut (Giordano and Mann) In animals with gallbladders, there is such a papilla, and bile enters the duodenum intermittently because of contractions of the sphincter of Oddi. Pressures in different species have been found to vary from a minimum of 7.5 cm to a maximum of 40 cm. of water (Giordano and Mann, Herring and Simpson, Doubilet and Colp) Numerous investigators have given slightly different values for the normal intraductal pressure in man, but the range has been from 8 to 16.5 cm. of water (Doubilet and Colp;

Giordano and Mann; Butsch, McGowan and Walters, Doubilet; Caroli; Deucher and Partington) This is the initial pressure or the measure of sphincter resistance. As a series of injections of a radiopaque medium is made during operative cholangiography, the common duct pressure rises slightly but usually returns to the initial pressure within a few minutes.

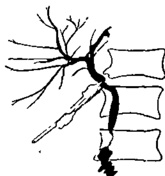



FIG 29A—B H, a 63 year old white male with hypertensive cardiovascular disease and a seven month history of sharp right upper quadrant pain without jaundice A cholecystogram revealed multiple small calculi in the gallbladder A thin-walled gallbladder containing several calculi was removed and the common duct drained because of excessive intraductal pressure. Bile taken at operation cultured *E. coli* and *Aerobacter aerogenes* An operative cholangiogram with manometry after 5 cc of the medium shows marked narrowing of the transduodenal segment of the common duct and little medium in the duodenum Pressure, 44 cm. of water

Rate of Injection. When manometry is performed with operative cholangiography, the pressure recorded in the common duct is influenced noticeably by the rate of injection. The sphincter of Oddi is sensitive to a rise in intraluminal pressure. Sudden distention of the bile ducts by too rapid injection of fluid is always followed by a spasm of the sphincter with an increase in intraductal pressure. This may reach the potential resistance of the sphincter which, according to Archibald, is 80 cm. of water. The spasm is generally transitory, and the pressure falls rapidly as soon as the injection is discontinued.

When the sphincter is hyperirritable, owing to the presence of infected bile in the duct system, injection of even a small amount of fluid slowly will suffice to induce a spasm of the sphincter. In one such case, the injection of 5 cc. of diodrast at 99° F. during a 21 second period raised the pressure from 19 to 44 cm. of

water. Further injections had to be made much more slowly to keep the pressure from exceeding 60 cm. of water (Figs. 29A and B).

Temperature of Injected Fluid. The temperature of the injected fluid should be measured by a thermometer and maintained as close to body temperature as possible. Too wide a deviation in either direction may produce sphincter spasm and a rise of the intrabiliary pressure. Caroli stated that a diminution in sphincter tone with low temperatures was demonstrated by Hitoo Iwanaga. In our experience, cooling the injection media to 50° F. causes an increase in sphincter resistance with a prolonged perfusion time. If 70 per cent diodrast is used, there



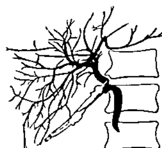


FIG 29B —An operative cholangiogram after the third injection (total 15 cc), showing complete obstruction of the transduodenal segment and filling of the fine intrahepatic radicles Pressure, 60 cm. of water.

is the added possibility that precipitation may occur in the syringe. Small increases in the temperature of the media are also sufficient to increase the tone of the sphincter. Fluid at 102° F. is able to produce an intrabiliary pressure of 35 cm. of water with cholangiographic evidence of sphincter spasm (Figs. 30A and B).

Caroli expressed the opinion that the perfect injection apparatus should be equipped with an insulating device similar to a thermos bottle around the syringe

[illegible] water.

[illegible] depends on the tone or state of contraction of the sphincter of Oddi, any abnormality of the sphincter, either transitory or prolonged, will affect this pressure. Increases in

tone are associated with elevations in pressure, and decreases, with drops in pressure. The increase in sphincter tone or spasm is rarely sufficient to prevent any opaque medium from entering the duodenum. When complete occlusion due to spasm occurs with a calculus impacted in the ampulla, the common duct pressure rises rapidly toward the potential resistance of the sphincter (Figs. 3 and 31). No attempt has been made to check Archibald's statement that spasm of the sphincter may withstand 80 cm. of water, as rupture of the fine bile canaliculi was feared. Pressures of 60 cm. of water, however, have been recorded in several instances (Figs. 3, 29, and 31)



Fig 29C—Postoperative cholangiogram with manometry after 16 days, showing a normal common duct with a pressure of 9 cm of water

With lesser degrees of spasm of the sphincter of Oddi, with or without calculi, the initial pressure is generally higher than normal. With succeeding injections, the pressure increases, falling slightly at the end of each injection, but reaching higher and higher plateaus (Figs. 19 and 30). The sudden drop in intraductal pressure caused by the surgical opening of the duct frequently is sufficient to relieve transitory spasm of the sphincter of Oddi, a fact manifested on subsequent T-tube cholangiograms. The hypotonic sphincter of Oddi described by Mallet-Guy has not been encountered in this series

Drugs. Morphine pantopon, demerol, and drugs with similar action probably have the most profound effect on the tone of the sphincter of Oddi and consequently on bile duct pressure (Fig. 14B). Morphine produces a marked increase

in sphincter tone which persists for hours and does not appear to be counteracted by combination with atropine or scopolamine in the usual dosage.

When morphine is used preoperatively in patients whose disease is limited to the gallbladder, the initial pressure in the common duct is at the upper limit of normal, approximately 16 to 18 cm of water. If morphine is omitted, the initial pressure is at the lower limit of normal, i.e., 8 to 10 cm. of water. Morphine, given



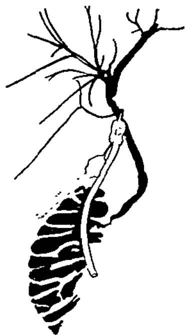


FIG 30A —A J., a 33 year old white male with a four year history of severe epigastric pain radiating substernally The pain was worse for one month but not associated with jaundice. The gallbladder failed to visualize by cholecystography A chronically thickened gallbladder containing calculi was removed An operative cholangiogram with manometry after 5 cc. of the medium shows narrowing of the transduodenal segment with visualization of the main hepatic branches

as preoperative medication to patients with biliary dysfunction, increases the sphincter tone, with the result that the patient may arrive in the operating room complaining of biliary colic. Barbiturates, on the other hand, such as phenobarbital and pentobarbital, do not affect the tone of the sphincter appreciably.

Doubilet and Colp reported marked increases in sphincter resistance following the instillation of 0.9 per cent hydrochloric acid in the vicinity of the papilla of

Vater by means of a duodenal tube. They noted rises from an initial pressure of 16 cm. to 26 cm. of water.

The most effective antispasmodic drugs used to decrease the tone of the sphincter of Oddi include the nitrites, atropine, and papaverine. Since the majority of cases in the present series have been operated on under general anesthesia, medications have been given intravenously. Aminophylline decreases common duct pressure somewhat with a maximum effect in approximately 12 minutes. An extensive study of this drug has not been made because of the prolonging of the operation necessitated by this delayed response.

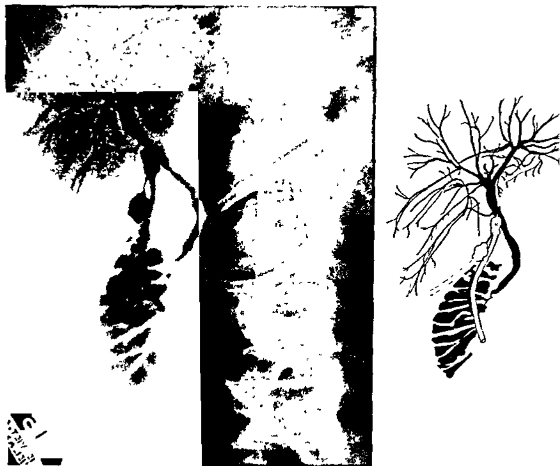


FIG. 30B.—An operative cholangiogram after the third injection (total 15 cc.), showing persistent narrowing of the transduodenal segment and filling of the fine intrahepatic radicles. The common duct pressure was 35 cm. of water.

Anesthesia. After allowance for the preoperative use of morphine, no constant change in common duct pressure can be attributed to the anesthetic agent. The anesthetic used in the majority of cases has been intratracheal nitrous oxide, oxygen, or ether. Recently, this has been supplemented by curare. Spinal anesthetics as well as local blocks have been used in a number of instances, a few supplemented by intravenous sodium pentothal. Mallet-Guy stated that sodium pentothal is not a satisfactory anesthetic because in dogs it causes a rapid and

marked drop in biliary pressure. In our experience with humans, this has not been observed, in spite of doses up to 2.5 gm. of the drug.

Spasm Following Exploration. Mechanical trauma to the common duct and the sphincter of Oddi incurred during instrumental removal of an impacted stone provokes severe and prolonged spasm of the sphincter (Fig. 32). No opaque medium passes into the duodenum, and the pressure rises abruptly, limited only by cessation of the injection. Whenever it is possible to remove



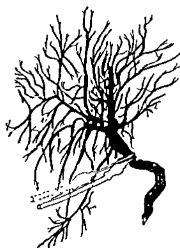


Fig 31 –H J, a 54 year old white male with a history of cholecystostomy three months previously for acute cholecystitis associated with obstructive jaundice Indigestion continued postoperatively without weight loss The gallbladder failed to visualize on the cholecystogram. A chronically thickened gallbladder containing small stones and mud was excised, and similar material was removed from the common duct. An operative cholangiogram with manometry shows a small stone in the terminal common duct with filling of fine biliary radicles The common duct pressure was 54 cm of water

calculi from the common duct without instrumentation, the contrast medium enters the duodenum freely, and the pressure rise in the common duct approximates that recorded in patients whose disease is limited to the gallbladder.

Correlation of Common Duct Pressure with Roentgenogram

There is a striking correlation between the cholangiogram and the simultaneously recorded common duct pressure. When the common duct is capable of little change in diameter, any increase in intraductal pressure is obvious cholan-

giographically by the extensive filling, and, at times, dilatation of the intrahepatic biliary radicles. If the pressure reaches 50 to 60 cm of water, this filling appears to extend almost to the capsule of the liver. As the pressure rises, dilatation of the bile ducts or pancreatic duct approaches a maximum (Figs. 3, 11, 29, and 31)

On a number of occasions, only the distal tip of the pancreatic duct had been visualized with pressures up to 20 cm. of water. At the third or occasionally at a



FIG 32.—G B, a 29 year old white male with a three year history of postprandial epigastric distress activated by greasy foods No history of jaundice The cholecystogram failed to show a gallbladder shadow. A T-tube operative cholangiogram shows the common duct clear after instrumental removal of three calculi Note the marked spasm of the sphincter of Oddi. (*Surg*, *Gynec & Obst*, 87.299, 1948)

fourth injection of the series, the pressure rose to 40 or 50 cm of water, with the simultaneous visualization of a long segment of pancreatic duct (Fig 19B). A collapse in the resistance of a sphincter or sphincter-like mechanism protecting the pancreatic duct from reflux might explain this observation.

A similar though somewhat rarer observation has been made with major intrahepatic biliary radicles The intrahepatic portion of the bile ducts may seem to be well filled, when suddenly on the third injection, a completely filled, new

biliary radicle is seen (Fig. 6A). This might be accounted for by the relaxation of a sphincter about the mouth of the major biliary radicle.

POSTOPERATIVE CHOLANGIOGRAPHY AND MANOMETRY

Postoperative cholangiography was used for the first time in 1926 by Saralegui. Since then this method has been used to prove the patency of the common bile duct and the absence of calculi in it, before removal of the T-tube. Secondary operations for the correction of persistent biliary fistulae or for jaundice which has recurred following the closure of such fistulas are infinitely more difficult without a guide to the common duct which may be lost in a maze of inflammatory adhesions.

Postoperative manometry was described originally in 1937 by Doubilet and Colp. It has been employed with cholangiography since 1941 by Caroli. Used together, they have provided a method of determining the status of the transduodenal segment of the common duct and the effect of drugs upon it.

TECHNIC

Postoperative cholangiography and manometry are best performed in the roentgen ray department, where advantage may be taken of fluoroscopy and spot films. For comparison of the results with those obtained by operative cholangiography, it is well to keep the two technics as similar as possible.

The same considerations which influenced the choice of media for operative cholangiography apply equally well for postoperative cholangiography. Anesthesia and preoperative medication are not factors in this examination. Owing to the absence of the action of morphine, the tone of the sphincter of Oddi is not increased.

The contrast medium is best injected through a double lumen T-tube. One lumen of the tube is relatively small and extends along the arm of the T which is placed in the distal end of the common duct. It serves for measuring pressures without the error introduced by the flow of the perfusing solution. It also serves as a vent for the evacuation of air bubbles when saline is injected through the large lumen prior to cholangiography When a solution such as ether is used in an effort to dissolve retained calculi, its instillation is facilitated and rendered painless by a slow injection through the small lumen of the tube, allowing the larger lumen to remain open for the escape of vapor and waste solution without an increase in bile duct pressure

Rotation of the patient about 10° to the right is done for the same reason as in the operative procedure. A spinal manometer for recording pressures is connected to the small lumen of the T-tube, and the zero point is placed at the estimated level of the common duct. After air bubbles have been expelled, 70 per cent diodrast or 75 per cent neo-iopax warmed to 98° F. is injected into the large lumen of the T-tube. The length of time required for the injection is recorded by a stopwatch.

Three injections of medium, each of 5 cc., are made under fluoroscopic control, with pressures recorded at the beginning and end of each injection. Films are taken during and after each injection. In addition to the usual films,

an emptying film is taken after 15 minutes to determine if there is any delay in the evacuation of the contrast medium.

Effect of Drugs

The action of various drugs on the common duct can be tested most adequately by postoperative cholangiography and manometry. In spite of this, there is considerable disagreement among various authors concerning the normal common duct pressure and the effect of different drugs on this pressure. Doubilet and Colp found a rise in common duct pressures in humans from an initial pressure of 16.5 cm. to 37 cm. of water following the injection of ¼ grain of morphine. Some effect was still apparent after four hours. Schuberth and Sjogren reported that morphine had no effect on the "ampulla" or on the passage of bile into the duodenum. Butsch, McGowan, and Walters, on the other hand, studying bile duct pressures through T-tubes in postcholecystectomy patients, found rises of 35 cm. of water following injection of 1/6 grain of morphine. Cholangiograms taken simultaneously showed spasm of the sphincter of Oddi. We have found similar and even greater rises in bile duct pressure following the administration of morphine in patients with dysfunction of the sphincter. In patients with normal biliary tracts, except for a diseased gallbladder, however, the only effect of morphine was to raise the initial pressure from the range of 8 to 12 cm. of water to that of 15 to 19 cm. of water. As long as the opaque medium was injected slowly, the pressure rarely rose more than a few centimeters during the injection and rapidly returned to the initial pressure.

Doubilet and Colp stated that atropine in 1/75 grain doses diminishes the irritability of the sphincter to such agents as 0.9 per cent HCl but does not lower its tone. Caroli was of the opinion that such a dosage of atropine was one of the best agents for dilatation of the choledochoduodenal junction. Certainly it appears unable to counteract the increased tone produced by morphine given in conjunction with it.

Of the various nitrites used, amyl nitrite seems capable of giving the most rapid and profound drop in common duct pressure. According to Caroli, this occurs within two minutes. Nitroglycerine gives a more transitory and less certain response. Aminophylline is fairly effective, and its action is more prolonged than either of the others. It may require 12 to 15 minutes to attain its maximal effect, even when given intravenously.

The effect of papaverine is controversial. Doubilet and Colp found it to be of no effect, even when given in doses of 64 mg. Eisenstein, on the other hand, found it to be the most effective drug for relaxing the sphincter of Oddi in dogs and for allowing the passage of calculi which had been introduced experimentally into the common duct. When given intravenously in small doses to postcholecystectomy patients, it seems to have little if any effect on the transitory spasm of the sphincter.

Febrile Reactions Following Postoperative Cholangiography

Occasionally, following postoperative cholangiography, there is an elevation of the patient's temperature, with or without a chill. Not infrequently, this reaction is attributed to diodrast or other contrast media. The temperature rise does not

occur immediately, however, but about 24 hours later. Culture of the common duct bile almost invariably reveals a mild cholangitis associated with infected bile as the source of the fever. Martensson reported several cases of cholangitis due to infected bile forced into the biliary tree. Even if the culture of the bile at operation shows no growth, it is advisable to culture the bile again before doing postoperative cholangiography and pressure studies.

Another common belief is that diodrast or neo-iopax causes pain occasionally when used for postoperative cholangiography while lipiodol does not. In all probability, the factor producing pain is a sphincter spasm brought on by excessively rapid injection of the medium. Lipiodol, being more viscous, is, of necessity, injected more slowly. With a hyperirritable sphincter, an injection rate which is slow for the ordinary patient may be fast enough to produce spasm.

PRESSURE FLOW STUDIES

Pressure flow studies, performed through the T-tube during the postoperative period, are probably the most useful method of determining the return of the biliary system to relatively normal physiology (Deucher and Partington). These studies are comparatively easy when performed through a double lumen T-tube; but even with such a tube, it is sometimes difficult to maintain a constant intrabiliary pressure.

Pressure Tolerance without Pain

The intrabiliary pressure which can be maintained without pain to the patient is known as the "pressure tolerance" It is determined by allowing sterile saline at body temperature to flow into the large lumen of the T-tube as rapidly as necessary to raise the biliary duct pressure, measured through the small lumen, to the point where the patient first feels pain. A pressure just below this point which can be tolerated by the patient without pain is called the "pressure tolerance." It is fairly constant for individual patients and does not change markedly with changes in the functional state of the bile ducts There is marked variation in pressure tolerance among individuals, however, and even in the same individual with changes in the temperature of the perfusion fluid. If the transduodenal segment is widely patent, it may be impossible to determine the "pressure tolerance" because the saline enters the duodenum too rapidly to permit a sufficient rise in biliary duct pressure to produce pain.

Perfusion Time

A more valuable test of the functional state of the biliary duct system is the determination of the "perfusion time" which is the time required for 100 cc. of saline at body temperature to enter the common duct through the T-tube at a given pressure. A water pressure of 20 cm. has been chosen arbitrarily for the current studies, as this is below the pressure tolerance of most bile ducts and yet is high enough to render the perfusion time relatively short. Even when the saline reservoir has a large capacity, there may be fairly well marked fluctuations in the bile duct pressure, usually necessitating several adjustments during the determination of the perfusion time. Comparison of several determinations

of the perfusion time made in the postoperative period gives a valuable index of functional improvement of the duct system. It serves as a most useful adjunct to postoperative cholangiography in determining when to remove the T-tube.

ALLEGED DISADVANTAGES AND RISKS OF CHOLANGIOGRAPHY

Alleged Disadvantages

Criticisms and objections to cholangiography have been directed for the most part toward operative cholangiography. One of the main criticisms of operative cholangiography is that it prolongs the operation. When performed as a routine by personnel familiar with their respective duties, however, the maximal time required for this procedure should be no longer than 10 to 15 minutes. If manometry is combined with cholangiography, the elapsed time approximates 20 minutes In the majority of instances, this time is not entirely lost. Unless further procedure must await the result of cholangiography, the surgeon can usually proceed with the indicated surgery. The additional 20 minutes is more than compensated for if, otherwise, the required information could have been obtained in no other manner than by a needless common duct exploration.

At times, confronted by a normal operative cholangiogram of a patient with none of the criteria for common duct exploration, the surgeon is inclined to wonder if the information obtained has been worth the time and effort. The discovery of a calculus in the ampulla of Vater or of a narrowing of the transduodenal segment in just such a case helps to justify the procedure and emphasizes the fallibility of commonly accepted criteria.

Early in any individual series of cases, an artefact or misinterpretation may lead to unnecessary exploration of the common duct or re-exploration if the examination has been performed through the T-tube. In most instances, air bubbles are the source of error. With increased experience and rigid precautions to keep air out of the injection tubing, this error can be reduced to a minimum.

Alleged Risks

The alleged risk associated with cholangiography has not been considered significant by those investigators who have used it most extensively. In 1945, Mirizzi reported its use in 1500 cases without complication, in spite of having employed it in all cases of suppurating angiocholitis.

Martensson, on the other hand, stated that in 1944 Odelberg reported 2 fatal cases of cholangitis with liver abscesses developing immediately after operative cholangiography in which jodairal forte had been used as the contrast medium. Martensson reported 2 of his own cases of ascending cholangitis and death after two and one half and five months, respectively, following operative cholangiography with jodairal forte as the contrast medium. In his opinion, the choice of medium might have been responsible. He emphasized the importance of *E coli* in the bile taken from the cystic duct and recommended that a direct smear be examined during the operation, to allow the institution of T-tube drainage in infected cases.

No case of ascending cholangitis has been observed in our series, although, because of this possibility, cholangiography was omitted in one case with a

cholecystocolic fistula. In 2 instances, the common duct was explored in spite of a normal cholangiogram because of an abnormally high pressure recorded during simultaneous manometry. In both cases, cultures of the common duct bile were positive for *E. coli* and *Aerobacter aerogenes.* T-tube drainage may have contributed to the uneventful convalescence of both patients.

Instances of severe biliary colic have been reported during postoperative cholangiography. The respective media employed have been blamed for this although they probably took no part in the production of pain. If the medium, warmed to body temperature, is injected slowly under manometric control, pain occurs only when the pressure tolerance is exceeded.

ADVANTAGES OF CHOLANGIOGRAPHY

Many advantages attend the routine use of both operative and postoperative cholangiography. Important and relevant information is made available which could not be obtained in any other way. The advantages associated with operative cholangiography apply principally to the planning and execution of the necessary surgery. The advantages associated with postoperative cholangiography apply to the postoperative management of patients with drainage of the common duct.

One of the chief advantages of operative cholangiography is that it permits an immediate evaluation of the anatomy and pathology of the biliary tract. With the information gained from this examination, a proper operative procedure, limited to the strictly necessary surgery, can be established Operative cholangiography is particularly important during secondary operations when the normal anatomic relationships are distorted by previous surgery and adhesions. Mirizzi described its value in pseudotumoral cholelithiasis with the entire hepatic space blocked by adherent organs and only the tip of the gallbladder available for injection of the contrast medium

Operative cholangiography permits the recognition of calculi anywhere in the biliary tract Their detection is not dependent on an instrumental search which may not disclose all of the calculi present, especially those in the hepatic radicles beyond the reach of instruments. Operative cholangiography through a T-tube is invaluable as a final assurance that all calculi have been removed. When no calculi are present, in spite of jaundice or a dilated duct, the unnecessary trauma of a common duct exploration may be avoided. This is of considerable importance with poor surgical risk patients or with cases of acute cholecystitis in which exploration is difficult because of hemorrhage and edema.

Noncalculous obstruction of the common duct, such as narrowing of the transduodenal segment from any one of the many possible causes and narrowing of the pancreatic segment because of pancreatitis, may also be recognized by cholangiography These conditions cannot be seen or felt at operation and, without cholangiography, are only inferred. When the common duct is narrowed and angulated, it may be impossible to insert an instrument through it into the duodenum. If cholangiography is not used, the surgeon remains unaware of the true status of the duct and may cause considerable damage if he persists in the exploration.

Incomplete obstruction of the common duct due to pancreatitis, especially if calculi are present, is an indication for some type of short circuiting operation utilizing anastomosis of the biliary tract to the intestine. This is facilitated if the need for such a procedure is fully appreciated before the gallbladder is removed.

A relatively complete occlusion of the common duct associated with obstructive jaundice and a mass in the head of the pancreas may represent carcinoma of the pancreas. By use of cholangiography, such a carcinoma may be differentiated from a stone impacted in the ampulla of Vater surrounded by an area of pancreatitis. It may be impossible, otherwise, to make the correct diagnosis even at surgical exploration.

Neoplasms of the intrahepatic ducts likewise may be overlooked during surgery Since the gallbladder and bile ducts are small, the surgeon usually concludes that he has explored a case of hepatitis by mistake. While a cure usually is impossible, palliative hepatostomy, as described by Mirizzi, is sometimes worth while. If a patient with hepatitis is explored because of the impossibility of ruling out obstructive jaundice on clinical evidence, the operation may be terminated promptly with less risk when a normal biliary system is demonstrated by cholangiography.

Following common duct injury and stenosis, it is sometimes extremely difficult to locate the proximal limb of the bile duct which may be buried in inflammatory adhesions. In such cases, Mirizzi used preliminary hepatic puncture and cholangiography with success.

Postoperative cholangiography provides a rational method for the management of patients with common duct drainage. The rare residual calculus is discovered, and efforts to remove it can be observed. Obstruction of the common duct by pancreatitis or any of the various types of narrowing of the transduodenal segment can be evaluated, and the appropriate time for removal of the T-tube or further surgical procedure may be chosen. The effect of antispasmodic drugs on common duct obstruction can be tested and the most effective one selected, thereby shortening the drainage period.

Thus cholangiography provides specific accurate information essential to good results in biliary surgery. Uncertainty and inference are replaced by planning and logic in the choice of operative procedures, with benefit to all concerned.

REFERENCES

Altman, W S.: Cholangiography, Fractional Method *Radiology*, 37:261, 1941

Baldwin, W. M. The Pancreatic Ducts in Man, Together with a Study of the Microscopical Structure of the Minor Duodenal Papilla *Anat Rec*, 5:197, 1911

Bernhard, F.. Die Bedeutung der Cholangiographie fur Praxis und Forschung. *Chirurg*, 9:201, 1937

Best, R. R. Cholangiographic Demonstration of the Remaining Common Duct Stone and Its Nonoperative Management *Surg, Gynec. & Obst.*, 66:1040, 1938

Best, R R, and Hicken, N F Cholangiographic Demonstration of Biliary Dyssynergia and Other Obstructive Lesions of Gallbladder and Bile Ducts *J A M A*, *107*:1615, 1936.

Best, R. R, and Hicken, N F Biliary Dyssynergia, Cholangiographic Recognition and Its Significance. *West. J Surg*, *44*:467, 1936

Bettman, R. B, Tannenbaum, W J, and Arens, R A.. Operative Cholangiography. *Surgery*, *13*:131, 1943.

Bonn, H. K.: Overlooked Common Duct Stone *West J Surg*, *44*:563, 1936.

Boyden, E. A.: Sphincter of Oddi in Man and Certain Representative Mammals. *Surgery,* 1.25, 1937.

Boyden, E. A.. Pars Intestinalis of Common Bile Duct, as Viewed by Older Anatomists (Vesalius, Glisson, Bianchi, Vater, Haller, Santorini, etc) *Anat Rec*, 66 217, 1936

Caroli, J: Radiomanometry of the Biliary Tract. Medical Research in France during the War. *Editions Médicales Flammarion*, 1939-45, 87.

Carter, R. F.: Benign Fibrous Stenosis of Common Bile Duct *Am. J Surg*, 30 110, 1935.

Carter, R. F, et al.: Etiology of Stone in Common Bile Duct *Arch Surg*, 40 103, 1940.

Cattell, R. B.: Benign Strictures of Biliary Ducts. *J.A.M.A.*, 134.235, 1947.

Clute, H. M.: Common Duct Stones, *J A M A*, 95:1568, 1930

Colp, R.. Postcholecystectomy Syndrome and Its Treatment. *Bull New York Acad. Med*, 20.203, 1944.

Colp, R, and Ginzburg, L.: Mortality in Surgical Diseases of Biliary Tract, Analysis of 130 Autopsies. *Ann. Surg.*, 105.9, 1937.

Colp, R., Doubilet, H, and Gerber, I E Endocholedochal Section of Sphincter of Oddi. *Arch. Surg*, 33.696, 1936

Copher, G. H., and Illingworth, C. F. W.: Further Studies on the Emptying of the Gallbladder *Proc. Soc Exper Biol & Med*, 25.172, 1927

Counseller, V. S., and McIndoe, A H Dilatation of Bile Ducts (Hydrohepatosis). *Surg, Gynec. & Obst*, 43.729, 1926

Croswell, C. V.: Congenital Anomaly and Extrahepatic Ducts of Gallbladder. *J. Tennessee M. A*, 27.316, 1934

Deucher, R. G, and Partington, P F. Unpublished data

Doul [illegible] 'isualization of Biliary Tract after [illegible]

Doul [illegible] in Human. *Surg, Gynec. & Obst*, 64.622, 1937

Doubilet, H., and Mulholland, J H.. The Surgical Treatment of Pancreatitis *Surg Clin North America*, pp 339-359, 1949.

Editorial. Strictures of Common Duct *Surg, Gynec & Obst*, 82.104, 1946.

Eisenstein, M. W. Study on Relief of Obstruction in Common Bile Duct and in Papilla of Vater *Surg, Gynec & Obst*, 89 49, 1949

Giordano, A S, and Mann, F C. Sphincter of Choledochus. *Arch. Path & Lab. Med*, 4 943, 1927

Goni Moreno, I Dispositivo para colangiografía operatoria después de la coledocotomía. *Bol y trab, Acad argent de cir*, 30 142, 1946

Hagan, H, and Townsend, H L The Clinical Evaluation of Cholangiograms. *Ann Surg* 127.810, 1948

Halsted, W S Retrojection of Bile into the Pancreas, a Cause of Acute Hemorrhagic Pancreatitis *Johns Hopkins Hosp Bull*, 12 179, 1901.

Herring, P. T, and Simpson, S The Pressure of Bile Secretion and the Mechanism of Bile Absorption in Obstruction of the Bile Duct. *Proc Roy Soc London (s B)*, 79 517, 1907

Hicken, N. F., and Crellin, H. G: Congenital Atresia of Extrahepatic Bile Ducts. *Surg, Gynec. & Obst*, 71 437, 1940

Hicken, N F, Best, R R, and Hunt, H B Cholangiography, Visualization of Gallbladder and Bile Ducts during and after Operation. *Ann Surg*, 103 210, 1936.

Hicken, N F, Coray, Q. B, and Franz, B Anatomic Variations of the Extrahepatic Biliary System as Seen by Cholangiographic Studies *Surg, Gynec & Obst.*, 88.577, 1949.

Hicken, N F, White, L B., and Coray, Q B Incomplete Removal of Cystic Duct as Factor in Producing Postcholecystectomy Complications. *Surgery*, 21 309, 1947.

Hicken, N F, White, L. B, and Coray, Q B External Biliary Fistulas, Study of 23 Cases. *Surg, Gynec. & Obst*, 74 828, 1942

Hill, H A.. Functional Disorders of Extrahepatic Biliary System Biliary Dyssynergia or Dyskinesia *Radiology*, 29 261, 1937.

Hopkins, N K.: Congenital Absence of Common Duct, Three Cases in One Family. *Journal-Lancet*, 61.90, 1941.

Hunt, H. B., Hicken, N. F., and Best, R. R.: Exploration of Bile Ducts by Cholangiography during and following Operation *Am. J Roentgenol*, *38*.542, 1937

Ivy, A C Personal communication

Ivy, A C, and Sandblom, P: Biliary Dyskinesia. *Ann Int. Med*, *8* 115, 1934.

Kaijser, R Über das Cholangiographiebild bei Kompression oder Striktur des distalen Choledochusabschnittes nebst einigen Bemerkungen uber Diagnose und Therapie bei Carcinoma papillae Vateri (Im Anschluss an einen operierten Fall). *Acta med. Scandinav*, supp 170, pp 463-499, 1946

Kozoll, D D, and Necheles, H: Study of Mechanics of Bile Flow, Responses to Physiological Intravenous Solutions *Surg, Gynec & Obst*, *74* 27, 1942.

Lahey, F H Discussion of "Cholangiographic Demonstration of Biliary Dyssynergia" (Best and Hicken) *J A M A*, *107*.1619, 1936.

Lasala, A J. Ictericia obstructiva, diagnóstico clínico, oportunidad del tratamiento quirúrgico e importancia de la colangiografía operatoria para el diagnóstico etiológico y la conducta quirúrgica *Prensa méd. argent*, *34* 627, 1947.

Lasala, A J Ictericias obstructivas: importancia de la colangiografía operatoria. *Rev Asoc med argent.*, *58*.1006, 1944

Leven, N L. Reflux into Major Pancreatic Duct during Cholangiography. *Proc Soc. Exper Biol & Med*, *38* 808, 1938.

Macdonald, I G.: Histology of the Biliary Ducts and Its Correlation with Symptomatology of Common Duct Stone *Surg, Gynec. & Obst*, *60*:775, 1935.

McGowan, J M, Butsch, W. L, and Walters, W: Pressure in Common Bile Duct of Man, Its Relation to Pain Following Cholecystectomy. *J.A.M A*, *106*:2227, 1936

Mallet-Guy, P. Les interventions vagales dans le traitement de la maladie du sphincter d'Oddi *Acta chir belg*, *48*.128, 1949

Mallet-Guy, P. Conditions techniques du contrôle manometrique et radiologique. *J. Internat de chir*, *8* 989, 1948

Mallet-Guy, P.. Recidives après cholécystectomie *Bruxelles méd*, *28*.2603, 1948

Mallet-Guy, P., and de Beaujeau, M J.: Résultats éloignés de la splanchnicectomie unilatérale dans le traitement des états d'hypotonie des voies biliaires *Lyon chir.*, *43* 157, 1948.

Mallet-Guy, P, and Jeanjean, R Contrôle fonctionnel de la sphinctérotomie pour maladie du sphincter d'Oddi *Lyon chir*, *42* 299, 1947.

Mallet-Guy, P, and Koppes, R. La cholécystectomie sans drainage, à propos de 116 interventions pratiquées sous contrôle manométrique et radiologique per-opératoire *Lyon chir*, *42* 543, 1947

Mallet-Guy, P., and Lacour, R Du déterminisme du syndrome cholédocien de Villard *Lyon chir*, *42* 783, 1947.

Mallet-Guy, P, Blondet, P, and Moyson, M: Dystonies des voies biliaires et ulcères gastroduodénaux *Lyon chir*, *44*:27, 1949

Mallet-Guy, P, Guillet, E, and Durand, L Le reflux dans le canal de Wirsung au cours des cholangiographies *Lyon chir.*, *43*.653, 1948

Mallet-Guy, P, Jeanjean, R, and Feroldi, J La maladie du cystique, stases vésiculaires par hypertonie et éventuellement sclérose du sphincter de Lutkens *Lyon chir*, *42*.174, 1947

Mallet-Guy, P, Jeanjean, R, and Marion, P: *La chirurgie biliaire sous contrôle manométrique et radiologique per-opératoire* Paris: Masson & Cie, 1947.

Mallet-Guy, P, et al Duodéno-pancréatectomie pour cancer de la tête du pancreas, guérison *Lyon chir.*, *43* 51, 1948.

Martensson, K Grave Ascending Cholangitis Following Cholangiography Carried out through Cystic Duct Infected with *E Coli* Clinical and Experimental Study *Acta chir Scandinav*, *94* 1, 1946

Mirizzi, P. L. Colangiografía operatoria, catorce años de experiencia *Prensa méd argent*, *32*.1887, 1945

Mirizzi, P L. Functional Disturbances of Choledochus and Hepatic Bile Ducts. *Surg, Gynec. & Obst*, *74*.306, 1942

Mirizzi, P L.. Operative Cholangiography, Its Contribution to Physio-pathology of Common Bile-Duct *Lancet*, *2* 366, 1938.

Mirizzi, P. L.: Orientations nouvelles en chirurgie des voies biliaires *Presse méd.*, *45*:533, 1937.

Mirizzi, P. L.: Operative Cholangiography *Surg*, *Gynec & Obst*, *65* 702, 1937.

Mirizzi, P. L. Diagnostic des obstructions incomplètes non calculeuses du cholédoque, leur traitement par la cystico-duodénostomie *Presse med*, *44* 150, 1936

Mixter, C. G.: Personal communication

Saralegui, J A.. Cholangiography, New Technique and Results *Am J Roentgenol.*, *32*:167, 1934.

Schubert, O. O, and Sjogren, S E On Cholangiography *Acta radiol*, *22*.760, 1941

Sjogren, S. E.: Divertikelahnliche Bildung am Choledochus, Nachgewiesen durch Cholangiographie *Acta radiol.*, *22* 318, 1941

Smedal, M. I., and Sornberger, C F Cholangiography *Surg Clin North America*, pp 605-611, 1948

Sosman, M. C.: Discussion of Rigler and Mixer's paper, "Cholangiography and Biliary Regurgitation" *Radiology*, *48* 471, 1947

Sterling, J A., et al: Analysis of Postoperative Cholangiograms *Surg*, *Gynec. & Obst.*, *89*.292, 1949

Sturm, F: Erfahrungen mit der Cholangiographie *Zentralbl f Chir.*, *59* 891, 1932.

Tabbal, G. Colangiografias e cirurgia das vias biliares em Buenos Aires *Rev. med. Rio Grande do Sul*, *2*:197, 1946

Tenney, C. F., and Patterson, S H Injection of Bile Ducts with Bismuth Paste and Observations on Flow of Bile *J A M A*, *78* 171, 1922.

Thiessen, N W Anatomy of Sphincter of Oddi *Am J Surg*, *53* 94, 1941

Troup, R. L.. Visualization of Biliary and Pancreatic Ducts by Use of Sodium Iodide. *Radiology*, *18* 139, 1932

Velasco-Suárez, C Sobre un Nuevo Procedimiento de Exploración de la Porción Terminal de Colédoco *Bol y trab de la Soc de cir de Buenos Aires*, *20* 853, 1936.

Walters, W Discussion of Best and Hicken's paper, "Cholangiographic Demonstration of Biliary Dyssynergia" *J A M A*, *107* 1620, 1936

Walters, W, and Thiessen, N W Visual Methods of Studying Physiology of Common Bile Duct, Problem of Pancreatitis and Sphincteritis *Proc Staff Meet*, *Mayo Clin*, *9*.772, 1934

Westphal, K.. Muskelfunktion, Nervensystem und Pathologie der Gallenwege. *Ztschr. f klin med*, *96* 22, 1923

Young, E L, Jr Possibilities of Failure in Removal of Stones in Biliary Tract *New England J Med*, *200* 1145, 1929

Regional Enteritis

LELAND S. McKITTRICK, M.D. AND THOMAS S. RISLEY, M.D.

INTRODUCTION

INFLAMMATORY LESIONS of the small bowel have been encountered by surgeons for many years. For want of better classification they are usually diagnosed as "granuloma" or "tuberculosis." However, in 1932, Crohn, Ginzberg, and Oppenheimer described 14 cases of inflammatory disease involving the terminal ileum. Thirteen of the cases had resections, and the specimens were studied pathologically. Since no definite evidence of tuberculosis was found, they were designated as a separate entity and called "terminal" or "regional enteritis." Since that time, the disease has been found to involve other parts of the small bowel and even the large bowel. Many other cases have been recognized and reported, and the more inclusive term, "regional enteritis," is more generally used today.

ETIOLOGY

The etiology is unknown. Various theories as to bacterial, virus, or vascular origin have been advanced but without proof. It has not been possible to reproduce the disease in animals. The similarity to tuberculosis and sarcoid is suggestive only, and tubercle bacilli have never been recovered from the lesions.

INCIDENCE

The incidence, too, is not accurately known. The number of cases reported has appeared to increase each year, but this has been attributed to more widespread recognition of the disease. It is, however, a relatively rare condition. For instance, at the Massachusetts General Hospital, for the 10 year period from 1938 to 1948, the diagnosis was made in only 65 patients.

Age

Regional enteritis is largely a disease of young adults. The highest incidence in our series was in the third decade, but the range was from 12 to 71 years.

Sex

Reports seem to conflict. Although most series reported are not large, the distribution between male and female would seem to be about equal. However, in our series there were 23 males and 42 females.

which leads one to suspect the true nature of the obstruction and the diagnosis may be made only at laparotomy.

The diarrheal or colitis-like group comprises the greatest number of cases (42 per cent in our group). The history almost always mentions abdominal cramps (86 per cent of our cases) and usually weight loss and fever. Stools may be soft or watery, and there may be up to 15 or 20 per day. Blood was noted by the patient in 46 per cent of our cases, contrary to the usual idea that the diarrhea is nonbloody. However, positive guaiacs were found in only 25 per cent of the cases examined. The presence of ulcerations in most of the resected specimens leads one to believe that melena is more common than is usually appreciated. A history of rectal fissures, fistulas, and abscesses is not uncommon. Temperature and local tenderness are usually found. A mass may be present. Laboratory studies reveal anemia and leukocytosis in about half of the cases.

ROENTGENOGRAPHIC EXAMINATION

Both large and small bowel should be studied. It is fortunate that the barium enema is so often positive (52 per cent in our series) for it may be the only roentgenogram ordered in patients with diarrhea Frequently involvement of the terminal ileum is demonstrated by the reflux of barium into this segment of



FIG 1.–Roentgenogram of the small intestine in a case of regional enteritis, showing the "string sign" and dilated bowel proximal to the narrowed portion (in this case, below).

Race

The reported predilection for people of Jewish extraction may be more apparent than real, because many of the reports come from hospitals where a high proportion of Jewish patients is seen.

Temperament

In more than 80 per cent of our cases there was a statement to the effect that the patient was "nervous" or "high strung." Whether this is a cause or effect may be open to some question, but one might put a higher incidence among the more excitable individuals

PATHOLOGY

Grossly the involved bowel is thickened, edematous, and rigid (Fig. 3). It may be dilated or stenotic The surface may be reddened, covered with petechial hemorrhages or with fibrin The mesentery is greatly thickened and edematous The edema of the fat makes the bowel appear to sink into the mesentery. The regional lymph nodes are almost invariably enlarged and succulent. The mucosa may show ulcerations and pseudopolyps, accounting for the melena which may occur The ulcers may perforate either into the peritoneal cavity or into a hollow viscus, such as another loop of bowel or the bladder. The extent of the inflammation usually causes adherence of surrounding structures prior to the perforation so that spreading peritonitis is rare, and a local abscess is more likely to result. Matted bowel about an abscess accounts for many of the palpable masses. If there is a recent abdominal incision, the abscess may dissect through it and form a fecal fistula

The microscopic picture is that of a granuloma with chronic inflammatory cells, epithelioid cells, giant cells, and fibroplasia

CLINICAL PICTURE

The disease usually manifests itself by presenting one of four clinical pictures which vary according to the stage of the disease It may simulate an acute surgical abdomen, intestinal obstruction, ulcerative colitis, or present intestinal fistulas. There are other patients who have no symptoms, in which case the diagnosis is made incidentally by roentgen ray or at operation. One of our cases had no symptoms or signs other than massive rectal bleeding.

The acute form (23 per cent of our group) is most often confused with acute appendicitis. It may be indistinguishable so that laparotomy cannot be avoided, but usually one finds that the tempo is slower and it is less fulminating than appendicitis The onset is more insidious, and the duration of symptoms is longer, but the temperature may be higher. It should be suspected if a mass is palpable sooner than one would expect to find it in appendicitis Muscle spasm and signs of peritoneal irritation were conspicuously absent in our series

The obstructed group (15 per cent of our cases) presents the picture of subacute, rarely complete, intestinal obstruction with or without antecedent history

On the other hand, if at operation regional enteritis is encountered instead of acute appendicitis, the question of what to do must largely depend on the severity and extent of local findings. The entire small bowel from the ligament of Treitz to the cecum must be searched for "skip areas." Most surgeons are in agreement that, if the findings are mild and not too extensive, nothing should be done because of the favorable incidence of spontaneous cure in the mild cases.

If the decision is made to leave the diseased bowel alone, should the appendix be removed? We are not sure of the correct answer. Obviously, if the appendix or cecum is involved in the inflammatory reaction it should not be disturbed.



Fig 2 – Roentgenogram showing multiple fistulas between the terminal ileum and the cecum in a case of regional enteritis.
(Courtesy of Dr S F Marshall, Lahey Clinic, Boston)

If the diseased area is some distance from the appendix, appendectomy alone should not increase the risk of the laparotomy. Thus, in the cases reviewed by us there were 13 in which appendectomy was done in the presence of regional enteritis without subsequent fistula formation. On the other hand, 5 cases seen for fistulas had had appendectomies done at outside hospitals. When one considers that the fistulas do not come from the appendicial stump but rather from a loop of ileum, one realizes that it is not so much the appendectomy as it is the making of an abdominal incision and local manipulation which created a path for and possibly stimulated fistula formation.

The exact status of elective surgery in the management of this condition is

small bowel A motor meal will usually give the diagnosis, but not always. Since it failed to show disease in 32 per cent of our cases which were later operated on, it should not be relied upon exclusively.

The characteristic roentgenographic changes have been described by Kantor, the best known of which is the "string sign" or a diffuse filling defect of the bowel so that the barium appears as a piece of string (Fig. 1). Dilated bowel above, the conical shape of the barium shadow, and occasionally ileal stasis are other signs suggesting the presence of regional enteritis.

Any part of the gastro-intestinal tract from the duodenum down may be involved (Table I). All of our 60 operated cases had involvement of the small intestine. The entire small bowel was involved in 4 cases, the jejunum alone in 4 cases, the cecum in 22 cases, ascending colon in 2 cases, transverse colon and splenic flexure in 1 case, and sigmoid in 3 cases. In addition, 4 cases were later diagnosed as ulcerative colitis and required ileostomy.

TABLE I

OPERATIVE FINDINGS IN 60 CASES

Small Bowel Involvement—60	
Entire	4
Ileum	56
Jejunum	4
Large Bowel Involvement	
Cecum	22
Ascending colon	2
Transverse colon	1
Splenic flexure	1
Sigmoid	3

Fistula formation represents a late stage of the disease and almost always follows previous operations. However, one of our cases developed a spontaneous fistula to the abdominal wall without ever having been operated on. The fistulas may go to the abdominal wall, another loop of small bowel, the large bowel, or the bladder. Roentgen examinations are of great value in studying the course and origin of the tracts (Fig. 2).

TREATMENT

There is no known specific treatment for this disease. Surgical excision of the involved segment has so frequently failed to control the disease that it is no longer considered to be the treatment of choice except for specific indications

Medical treatment, while nonspecific, permits spontaneous healing to occur as it did in 6 of our patients for whom only exploratory laparotomy and appendectomy were done and who are now apparently well. There is no evidence that any of the antibiotics are of value.

Operations are usually done in the acute phase because acute appendicitis cannot be excluded, not because the acute phase of regional enteritis is an indication for operation. If the diagnosis can be made with certainty and acute appendicitis is excluded, laparotomy is not indicated. A spontaneous cure may result, and, if not, the complications may be treated if and when they arise.

When the disease is localized to a single area of bowel and when all disease including the enlarged nodes can be safely removed in a single definitive procedure, excision is probably the treatment of choice.

Disease in the ileocecal region lends itself well to a defunctioning ileotransverse colostomy. This operation is definitely indicated in the presence of an acute or chronic inflammatory process with local abscess or fistula formation, when there is marked lymphatic involvement of the mesenteric nodes or late obstruction in a patient in poor general condition.



Fig. 3—Photograph of a resected specimen of the terminal ileum and cecum showing the thickening of the bowel wall and the narrowing of the lumen in the area between the two hemostats

Vagotomy

Our experience with vagotomy is limited to one case in which only the right vagus was sectioned. The patient had extensive disease proved by laparotomy and is somewhat improved although partially incapacitated. Dennis et al. (1948) reported 22 vagotomies in the treatment of ulcerative colitis Two of the 14 cases which improved also had regional enteritis

COMPLICATIONS

Besides the abscesses and fistulas of the abdominal wall and the obstructions, there is a high incidence of rectal fissures, fistulas, and abscesses (17 per cent of our cases), probably secondary to irritation and chronic diarrhea. Proper absorption of proteins, fat, and fat-soluble vitamins may be interfered with in patients with extensive disease or in those who have had extensive resections or extensive sidetracking procedures. Anemia, hypoproteinemia, and hypocalcemia are encountered, and steatorrhea and tetany may result. The tetany may be severe and may be controlled only by huge doses of vitamin D.

not well established. Operation is clearly indicated for obstruction or fistula formation

There is much uncertainty in the minds of many surgeons relative to the comparative value of extirpation and internal defunctioning of the affected part. Increasing experience with this disease suggests that removal of the lesion is not essential to a good result, nor is there any assurance that if surgical removal is carried out the patient will be cured of his disease. A decade ago most surgeons in this country believed that surgical removal of the area of disease was indicated. In 1939, 25 of 27 surgeons sent questionnaires by Mixter favored resection in all but the very early cases. More recently there has been a definite trend toward the more liberal use of defunctioning operations Garlock and Crohn reported only a 10.5 per cent recurrence and no mortality following sidetracking procedures while there were 22 per cent recurrences and 12 9 per cent mortality after resections (Table II). In our own series (Table III) there was little difference between the two methods. At the present time, therefore, we do not advise an elective removal of the diseased segment as a second stage if there has been a satisfactory response to the defunctioning procedure.

TABLE II

RESULTS OF TREATMENT IN CASES REPORTED IN THE LITERATURE

		Resection		*Defunctioning Operations*		*Operations Not Specified*	
	Number of Cases	*Recurrence Per Cent*	*Mortality Per Cent*	*Recurrence Per Cent*	*Mortality Per Cent*	*Recurrence Per Cent*	*Mortality Per Cent*
Shapiro (literature)	378	18	7.2	28 4	7 9		
Garlock and Crohn (literature and own)	164	27.9	14 1	13 8	0		
Garlock and Crohn (own cases)	137	22	12.9	10 5	0		
Koster	80	15	14	13	6 7		
Ginzberg and Garlock	77	13	17	13	0		
Dixon	43	10	6 9	36	29		
Miller and Warren	43	65	12	0	60		
Present series	65	33	13	37	16		
Mixter	278					20	14
Rhoads	125					9 2	8 8

TABLE III

RESULTS OF TREATMENT IN 55 CASES AT THE MASSACHUSETTS GENERAL HOSPITAL WITH ADEQUATE FOLLOW-UP

				Persistent Symptoms		*Deaths*	
Type of Treatment	*Number of Cases*	*Recovery*	*No Incap*	*Partial Incap*	*Total Incap*	*Hospital*	*Later*
Resection							
One stage	9	6		1			2
Two stages	8	6		2			
Secondary	7	1	1	2	2	1	
Defunctioning Operations							
Complete	18	9	1	3	2	2	1
Partial	1			1			
Conservative							
No operation	5	2		2			1
Exploratory (lap only)	1	1					
Appendectomy (only)	5	5					
Vagotomy	1			1			
Total ...	55	30	2	12	4	3 +	4 = 7

Finally, the relation to ulcerative colitis is not clear. The frequent involvement of the large bowel is suggestive. A certain number of cases (4 in our series) which have had early diagnoses of regional enteritis will later manifest findings consistent with ulcerative colitis and may require ileostomy.

REFERENCES

Crohn, B. B., Ginzburg, L., and Oppenheimer, G. D.: Regional Ileitis, a Pathologic and Clinical Entity. *J.A.M.A.*, 99 1323, 1932.

Dixon, C. F.: Regional Enteritis *Ann Surg*, *108* 857, 1938.

Garlock, J. H. Present Status of the Problem of Regional Ileitis. *Am. J Surg.*, 72.875, 1946

Garlock, J. H, and Crohn, B. B: Appraisal of the Results of Surgery in the Treatment of Regional Ileitis. *J.A M.A.*, *127* 205, 1945

Ginzburg, L., and Garlock, J. H.: Regional Ileitis *Ann. Surg.*, *116*.906, 1942.

Kantor, J. L.: Regional (Terminal) Ileitis, Its Roentgen Diagnosis. *J.A.M.A.*, *103*.2016, 1934.

Koster, H, Kasman, L. P., and Scheinfeld, W.. Regional Ileitis *Arch. Surg*, 32.789, 1936.

Mixter, C. G.. Regional Enteritis. *Surg*, *Gynec & Obst.*, 68.322, 1939.

Rhoads, J. E.: The Management of Regional Ileitis and Certain Other Ulcerative Lesions of the Intestines. *Pennsylvania M J.*, 42.1050, 1939

Shapiro, R.. Regional Ileitis; Summary of the Literature. *Am J. M. Sc.*, *198* 269, 1939.

Warren, R., and Miller, R. H. Regional Enteritis, Report of 43 Cases *New England J. Med*, 226.589, 1942.

Warren, S., and Sommers, S C: Cicatrizing Enteritis (Regional Ileitis) as a Pathologic Entity; *Analysis of 120 Cases. Am J. Path*, *24*:475, 1948

MORTALITY

Regional enteritis is a serious disease and the mortality is high (15 per cent in our series). Death may be due to extensive disease with inanition, to overwhelming sepsis from abscesses and fistulas, or to peritonitis from a perforation (Table IV). Amyloid disease may be found at necropsy. Postmortem examination

TABLE IV

CAUSE OF DEATHS IN 10 CASES OF REGIONAL ENTERITIS

Extensive disease with inanition	8
Includes cases with	
Bladder fistula	1
Abdominal wall fistulas	1
Ulcerative colitis and amyloid disease	1
? cord tumor	1
Peritonitis (presumably from ruptured sigmoid)	1
Overwhelming sepsis with multiple fistulas and abscesses	1

in one of the cases dying of extensive disease with inanition showed extensive inflammation of the bowel from the terminal ileum to the hepatic flexure with cicatrization and with fistulas to the abdominal wall and flank. Two of our deaths occurred early in the course of treatment, one of sepsis and one of rapidly progressing inanition, but the majority who died did so after a prolonged illness and multiple operative procedures.

RESULTS OF TREATMENT

In considering results of treatment one must try to distinguish between symptoms due to recurrent or residual disease and those due to a short functioning bowel, such as patients who have had extensive resections for strangulation, obstruction, or mesenteric thrombosis sometimes show.

In general, the early, milder cases seem to do well under any form of treatment but are probably best treated conservatively In the more advanced cases, the recurrence rate and mortality rate are both disappointingly high. Only 55 per cent of our cases were well at the time of this follow-up, 33 per cent had evidence of recurrence, and 13 per cent had died (Table III).

Failure to recognize "skip areas" or minimal areas of disease, failure to remove or defunction all bowel drained by enlarged nodes, and the use of sidetracking procedures in continuity have been suggested as possible technical reasons for recurrence or persistence of symptoms Advocates of resection claim that resection eliminates the focus for further extension, but since many patients having simple defunctioning procedures do well and others after removal of all gross disease do badly, resection is probably not the answer to the prevention of recurrence

Secondary procedures all too frequently become necessary. In fact, the average number of operations in our series was three, and one patient had nine. Occasionally a brilliant result can be obtained by a secondary procedure, but more commonly the benefits obtained are limited or temporary.

clinical picture than that seen in almost any other condition, making it difficult to distinguish that part of the patient's condition which is due to the colitis itself and those factors which are the result of the nutritional, electrolytic, and vitamin depletion.

The writers are particularly impressed by certain aspects of the so-called small bowel involvement. We have seen at least one patient return to the hospital after ileostomy with rapid weight loss and diarrhea associated with ulcerations readily demonstrable in the terminal ileum proximal to the ileostomy. He was completely and immediately relieved by a plastic procedure relieving the obstruction at the outlet of the ileostomy. The diarrhea promptly stopped, the ulcerations healed, there was rapid gain in weight, and this patient has remained well for nine years subsequent to that time Likewise, we are impressed with the fact that rarely, if ever, have we seen the disease involve the ileum proximal to the ileostomy in a patient who, following the ileostomy, had a remission and a period of complete relief. It is experiences of this type which lead us to suspect that much of what we have previously called small bowel involvement by ulcerative colitis represents nutritional and other changes along the gastro-intestinal tract which are secondary to the disease in the colon rather than a part of it.

Important also in the understanding of this disease is the recognition that the periods of remission may last for months or even years We know of one patient who after 12 years without symptoms had an acute and rapidly fatal exacerbation of his colitis We have seen another patient desperately ill after childbirth with a complete remission following ileostomy who became and remained perfectly well for a similar period, then had an acute fulminating exacerbation in the colon necessitating urgent colectomy for relief. It is experiences such as these that make the disease so unpredictable, treatment so difficult to evaluate, and decisions so difficult to make.

PATHOLOGY

The earliest change which can be detected in ulcerative colitis is a diffuse hyperemia of the mucosa. Edema and granularity of the mucosa then ensue so that the slightest trauma causes bleeding In the next stage, ulcerations form and undermining of the mucosa with bridging in between are characteristic lesions of the disease and diagnostic when found Submucosal abscesses may result and in advanced cases the entire mucosa may be destroyed Perforation of an ulcer may occur The islands of mucosa intervening between ulcerations may become edematous and appear as pseudopolyps True polyps are occasionally found. Grossly, the bowel becomes hose-like, thickened, and rigid In the usual surgical specimen the bowel has been defunctioned by a previous ileostomy so that the lumen is greatly decreased or even strictured or obliterated and the walls thickened. The mesenteric lymph nodes are usually enlarged and inflamed.

Microscopically, the picture is that of a nonspecific infection. The mucosa, if present, is edematous and congested. The submucosa and possibly the muscularis are thickened and infiltrated with round cells and leukocytes, including eosinophils. The serosa may be thickened also Granulomas are usually not present and the condition differs from regional enteritis in that the lymphatics are not dilated.

Ulcerative Colitis

LELAND S. McKITTRICK, M.D. AND THOMAS S. RISLEY, M.D.

INTRODUCTION

NONSPECIFIC ulcerative colitis may be defined as a diffuse, ulcerating lesion of the large bowel of unknown etiology. It may be acute and progressive in nature, it may be chronic or recurrent. It is most commonly seen as a series of remissions and exacerbations

CLINICAL COURSE

The clinical manifestations are varied The acute fulminating type may be abrupt in onset and run a short, progressive, and fatal course. In other instances, the onset is insidious, the course prolonged and either chronic or recurrent. Exacerbations of the disease are frequently initiated by an acute infection or an emotional upset.

Emphasis has been placed on the importance of emotional factors on the course of the disease One cannot but be impressed by the apparent emotional instability of many of these patients, particularly when they are acutely ill We have been even more impressed by the rapid and complete personality change which so frequently occurs following ileostomy and relief from the suffering and extreme debilitation of the disease. We believe, therefore, that ulcerative colitis, as we see it, is a serious organic condition, that its treatment is primarily medical and surgical, that in certain cases and on specific indications the psychiatrist may have a part in the over-all management of a given patient but that this part of the treatment is of secondary, not primary, significance For most patients, a physician who understands the disease and the patient who has it, and who appreciates the importance to these patients of a close patient-physician relationship will be best able to treat the emotional as well as the physical aspects of the disease.

While ulcerative colitis is most commonly seen in the left colon (the rectum itself being involved in some 90 per cent of all cases), the tendency is toward gradual involvement of the entire colon. Less commonly a localized segment of the large bowel may be involved Extension into the small bowel is frequently reported, and certainly ulcerations involving the small bowel, particularly the terminal ileum, are not infrequently seen in depleted patients with severe or long-standing disease. Whether these ulcerations represent the same type of lesion as the primary process in the colon or whether they are more frequently the results of nutritional, electrolytic, and vitamin deficiencies is open to question

The patient who is critically ill with ulcerative colitis presents a more complex

culosis is usually part of a more advanced process and will be recognized as such. Careful bacteriologic studies in an effort to exclude tuberculosis, bacillary dysentery, and amebic dysentery are a routine part in the careful study necessary before the final diagnosis is accepted.

ROENTGENOGRAPHIC EXAMINATION

"The diagnosis of advanced severe colitis is as a rule readily made by the roentgenologist. The typical 'lead pipe' appearance of the colon is well known and needs no discussion. Certain *pitfalls, however, occasionally lie in the way of* correct roentgen diagnosis, as, for example, when the outline of the descending and sigmoid portions of a normal colon may be so smooth as to simulate the 'lead pipe' appearance of colitis. The diagnosis of the occasional complicating carcinoma may be overlooked in certain instances when it is confused with severe mucosal swelling at the junction of normal and involved bowel or because of the *presence of fecal material. The necessity for proper preparation of the patient* for a barium enema is as important in ulcerative colitis as it is in other conditions. The belief of some clinicians that the bowel is clean because of the diarrhea accompanying the disease is erroneous It is essential that the patient with colitis have the usual preparation for a barium enema. Neither proctoscopy nor sigmoidoscopy should be performed with this preparation, however, since air is always introduced into the colon with the passage of the proctoscope, thus making accurate roentgen examination impossible. Pseudopolyposis is a term to be avoided: the so-called pseudopolyps may represent islands of swollen mucosa between ulcers in the acute phase of colitis or the fibrous tabs of scar formation in the chronic stage of the disease. The defect usually designated by this misnomer can be confused with true polyposis

"The diagnosis of ulcerative colitis in the early phases is extremely difficult for the radiologist; the clinical findings including proctoscopy and sigmoidoscopy are of much greater importance in obtaining the correct diagnosis. There are certain early roentgenologic signs which are suggestive of the incipient disease, however; careful search for them on the roentgenogram and increasing experience in their recognition may improve earlier diagnosis At best these signs are not easily recognized, nor are they infallible They consist of (1) mucosal swelling, and (2) the demonstration of multiple tiny ulcerations or serrations along the bowel margin. Proper preparation of the patient is a primary requisite to good films; good films are essential for correct interpretation.

"The postevacuation film furnishes the only accurate information regarding the mucosal pattern Swelling of the mucosa is found in the early phase of ulcerative colitis.

"Ulcerations when small produce on the roentgenogram only very fine serrations along the margins of the partially or completely filled colon. They may be difficult to differentiate from retained fecal material; the latter projects into the lumen while the serrations project beyond it Nevertheless, this difference is not easy to identify and frequently is impossible

"The roentgenologic findings of changes in the mucosal pattern and multiple fine serrations projecting beyond the lumen of the colon should suggest the diagnosis of idiopathic ulcerative colitis. It should be remembered, however, that

DIAGNOSIS

The diagnosis of ulcerative colitis may be easy or may be extremely difficult to make. Final diagnosis depends on a careful history, the results of sigmoidoscopic and roentgenographic examinations, and the exclusion of other ulcerating lesions of the large bowel, particularly tuberculosis, amebic dysentery, bacillary dysentery, carcinoma, and regional enteritis.

History

As already mentioned, this varies tremendously. The acute fulminating type may defy diagnosis by virtue of the acute onset, high fever, marked distention, and prostration. The diarrhea usually present may be severe to a point of incontinence. It is usually bloody, but we have seen the extensive destructive ulceration of the bowel with no gross blood in the stools and without diarrhea. Spontaneous rectovaginal fistula in the female is probably usually caused by ulcerative colitis

Sigmoidoscopy

This is the most useful and helpful procedure. Changes in the rectal mucosa will be present in from 90 to 95 per cent of all patients with ulcerative colitis. The proctoscopic findings will vary tremendously We usually do the examination without any preparation of the patient. No effort is made to pass the sigmoidoscope the full length unless nothing abnormal is seen in the rectum itself. The instrument should be passed with the greatest of care lest active bleeding be precipitated or injury done to the sensitive mucosa. It should always be preceded by digital examination which many times will give valuable information, revealing the thickened rectal wall and, in the more advanced cases, narrowing, stricture, and rigidity.

The appearance of the mucous membrane will vary In less severe cases one may see a mild erythema, a little edema, with a tendency to petechial hemorrhages when gently wiped with a swab. In the more advanced cases the mucous membrane is definitely edematous, the valves instead of being sharp are *rounded, the mucous membrane is diffusely red, a bit granular, and bleeds freely* even with gentle wiping. The blood vessels, normally so readily visible, disappear, and with the more marked edema and swelling, the narrowing of the lumen of the bowel can be seen In the rare instances when the lesion is limited to a more proximal segment of the bowel, the rectal mucosa will appear normal, although frequently bathed in a sanguinopurulent discharge which has come down from above. Ulcerations may or may not be noted. Of greatest importance is the fact that the process is diffuse rather than localized. The small, multiple, pinhead ulcerations may or may not be identified through the sigmoidoscope. In some of the more advanced cases, particularly with the larger ulcerations or areas of destroyed mucous membrane, the denuded areas are readily noted. Multiple small ulcerations seen in an otherwise normal appearing mucous membrane are much more characteristic of amebic dysentery than nonspecific ulcerative colitis. The isolated ulcerations occasionally seen which are due to tuberculosis will not be confused with ulcerative colitis. The diffuse type of colitis associated with tuber-

Because this concept of the treatment of this disease is in the experimental stage, we shall only refer to it at this time.

The one form of treatment which has been proved and is accepted at the present time is complete diversion of the fecal stream from the diseased segment of bowel by proximal exteriorization and division of the bowel. In most instances, and for all practical purposes, this means an ileostomy. There is the occasional left-sided lesion which is clearly localized to the left side where some favor a proximal transverse colostomy. We do not support this contention but favor an ileostomy as being more certain and little, if any, more troublesome.

In a selected group of patients, Ravitch has advised pulling the distal ileum through the sphincter in certain cases in which removal of both colon and rectum are indicated. We have had no personal experience with this procedure.

INDICATIONS FOR ILEOSTOMY

The decision to do an ileostomy on a given patient with ulcerative colitis may be one of the most difficult decisions in surgery. To decide when medical treatment is failing and when a continuation of such treatment will seriously jeopardize the life of the patient is at times extremely difficult. Too frequently the tendency in seriously ill patients is to postpone decision to do an ileostomy from day to day because of some favorable sign either on the chart, in the laboratory findings, or in the clinical picture, until finally the decision has been postponed too long and ileostomy will no longer prevent a fatal termination In acutely ill patients where response to medical treatment is unsatisfactory and where ileostomy seems indicated as a lifesaving procedure, it is our custom to plan intensive treatment for a given period of time, say one week, with the understanding that at the end of that time ileostomy is to be carried out unless there is distinct improvement in the condition of the patient. If, at the end of that week's time, there is not distinct improvement, ileostomy will be done. If, on the other hand, there is sufficient improvement to warrant the continuation of medical treatment, a program is again blocked off for a shorter period of time after which a re-evaluation is made with the understanding that definite progressive improvement must be manifest if operation is to be postponed longer The medical indications for ileostomy should be definite, and the operation must be understood by and acceptable to the patient. Not only must the disease be controlled, but the patient must be grateful for the health which has been regained. We feel strongly that until the patient recognizes the need for the help which ileostomy offers and has a real incentive to live, ileostomy may be inadvisable even though the medical indications seem clear.

In general, ileostomy is indicated for the following conditions: (1) failure of medical treatment, (2) massive hemorrhage, (3) pseudopolyposis, and (4) stricture or local perforation

FAILURE OF MEDICAL TREATMENT

The most difficult decisions to make are in those patients with the acute fulminating type of the disease. In general, few of these patients have been saved by ileostomy. Intensive treatment aggressively carried out is often successful. But

these changes may be duplicated by diffuse tuberculosis, diffuse amebiasis, and occasionally typhoid fever" (Robbins).

Occasionally one finds difficulty in distinguishing between carcinoma and ulcerative colitis. In general, however, if sigmoidoscopic examination reveals normal mucous membrane in the lower 10 inches of the bowel, careful roentgenographic studies of the bowel above that level will permit accurate interpretation of the symptoms

Regional enteritis will from time to time be confused clinically with the segmental form of ulcerative colitis Careful roentgenographic studies of the large and small bowel will usually distinguish between the two.

PRINCIPLES OF SURGICAL TREATMENT

It should be emphasized that basically the treatment of ulcerative colitis is medical Surgical treatment is reserved for those patients who, for one or another reason, have not responded to the medical regimen In considering surgery in the treatment of this disease, it is most important that one shall have a definite objective in mind. If one's objective in the management of ulcerative colitis is to control the disease at a level which permits only a restricted existence and in many instances a life of semi-invalidism, the attitude toward surgery will be quite different from what it will be if one's objective is to restore the individual to a state of relatively normal health and a more nearly normal existence.

We believe that the child with ulcerative colitis should live a relatively normal life, should develop in a normal way, and should take part in most of the usual

physically able to carry on a reasonably sound economic existence Once an ileostomy has been done, it is the obligation of the surgeon to carry through with whatever subsequent surgical procedures are necessary in order to reach this objective

With the above objectives in mind, the operations of primary importance in the management of ulcerative colitis are: (1) ileostomy, (2) subtotal colectomy, and (3) proctectomy Dennis has suggested transthoracic vagus resection as a possible mechanism of treating the disease He has carried out this procedure on 42 cases His present attitude toward this mechanism of treatment may be summarized as follows

"The group here is inclined to feel still that this procedure has not been proved to be the proper one to employ, and we are employing it, therefore, for the sole purpose of trying to evaluate it critically and impartially in order to learn whether it should be recommended for this type of disease. It seems to me that this is the only sensible course to take because of the immense amount of harm which would result if it were to be recommended for widespread use without careful and critical evaluation of the results over an extended period of years It is only in the fulminating cases, it seems to me, that one can be a little more positive about recommending the procedure."

INDICATIONS FOR COLECTOMY

Following ileostomy a patient will usually follow one of the following four courses: (1) There may be a prompt and complete disappearance of all signs and symptoms and the patient becomes and remains well indefinitely. (2) The initial response may be completely satisfactory for months or years but at some later time there is a reactivation of disease in the colon. (3) A few patients are helped but the relief from the disease is incomplete. They are better but not well. (4) Finally there is a small group which shows no apparent benefit from the ileostomy. Such patients usually have the acute fulminating type of disease which goes on to a fatal termination or belong to the group with massive hemorrhage for whom further aggressive surgery is indicated.

If the objective of the surgical treatment of ulcerative colitis is complete physiologic or anatomic elimination of the disease, the indications for colectomy are relatively clear. They may be grouped under the following headings:

As a Lifesaving Procedure

Recurrent massive hemorrhage which does not stop after ileostomy may require early removal of the colon and the rectum. Occasionally ileostomy fails to precipitate a remission in the acute form of the disease, or an acute exacerbation of the disease following ileostomy will not respond to medical measures, and removal of the colon is necessary in an effort to prevent death from continued activity of the disease in the colon.

Incomplete Response to Ileostomy

In those patients whose response to ileostomy has been less than completely satisfactory and in whom careful studies fail to show any other cause for failure to gain satisfactorily in weight and strength, the disease in the colon may be considered to be the limiting factor, and for these patients colectomy is indicated.

Reactivation of the Disease in the Colon

One exacerbation of the disease in the colon following ileostomy is a positive indication for colectomy. In our earlier experience, we allowed a patient at least two recurrences before advising the removal of the colon. Because of the seriousness of an acute exacerbation after ileostomy and because on one or two occasions the desire to postpone colectomy nearly cost the life of the patient, we have now come to feel that a single exacerbation is a positive indication for an elective colectomy. It should be done as an elective procedure during the same hospital admission after the acute process has been controlled.

Pseudopolyposis

After ileostomy the patient cannot exhibit the early symptomatic manifestations of cancer of the colon, and roentgen examination is often painful and unsatisfactory for detailed interpretation. Because of the increased incidence of carcinoma in patients with chronic ulcerative colitis and because of the fact that pseudopolyposis may be a predisposing factor, we believe that such a patient should have removal of the diseased colon.

the decision as to when this treatment has failed and when ileostomy may be necessary in an effort to save the life of the patient is a difficult one. It is our feeling that the prognosis following ileostomy in this group of patients is so poor that every possible effort should be made before operation is carried out. It is, nevertheless, true that the occasional patient who would otherwise die will be saved by ileostomy. It is for this reason that the decision to do an ileostomy should not be too long postponed.*

The patient who because of chronic illness or recurring acute episodes is a semi-invalid and unable to carry on a productive life and who has not responded satisfactorily to medical treatment should have an ileostomy.

MASSIVE HEMORRHAGE

This is one of the most serious complications of this disease. We have had little success in controlling this complication without operation, and in most instances, ileostomy alone will not suffice. The surgeon should be prepared to follow this by excision of that segment of the bowel from which the hemorrhage originates (see Colectomy).

PSEUDOPOLYPOSIS

Pseudopolyposis represents an intensive and late manifestation of the disease with the small islands of mucous membrane and granulation tissue resulting from the destructive process. It may or may not predispose to the formation of cancer. Published statistics of the incidence of cancer in ulcerative colitis vary from the 1.9 per cent in the 1,467 cases reported by Lynn to the 6.3 per cent of the 95 children reported by Jachman, Barzen, and Helmholtz. The 2 per cent reported by Cattell and Boehme probably fairly accurately represent the incidence of cancer in this disease, an incidence distinctly above the normal incidence of cancer of the colon in the general population of the same age. Whether the pseudopolyposis is a factor in or predisposes to the development of cancer is not definitely known. It does represent a late and extensive manifestation of the disease, and only rarely will a colon with such advanced disease be compatible with a state of good health.

STRICTURE OR LOCAL PERFORATION

Stricture or local perforation frequently with abscess formation likewise represents late manifestations of the disease and are indications for ileostomy.

ACTIVE COLITIS IN ASSOCIATION WITH A SECOND ACTIVE DISEASE

Infectious arthritis, superficial skin infections, occasionally tuberculosis, are not infrequently seen in conjunction with ulcerative colitis. It has been our feeling that when a patient is handicapped by two chronic diseases, one of which is curable by surgery, the elimination of the ulcerative colitis may be an important factor in controlling the other condition Most patients for whom ileostomy is undertaken under these conditions will have a subtotal colectomy as a planned procedure after an interval of two to three months.

* Dennis and his associates report excellent results following transthoracic vagus resection for a limited number of patients in this group.

Incision. We now prefer a small muscle-splitting incision through the mid-portion of the right rectus muscle so that the ileostomy will be at or just below McBurney's point. The length of the incision depends on the thickness of the abdominal wall and probably varies from 5 to 7 cm. in length. We handicap ourselves by working through a small incision merely to lessen the extent of the surgical wound and thus minimize future difficulties from possible wound infection.

Procedure. The incision is carried down through skin, subcutaneous fat, fascia, muscle, and peritoneum. Every effort is made not to put any gauze into the peritoneal cavity. With gentle retraction, the anterior abdominal wall is elevated slightly as one tries to identify the terminal ileum. This, at times, is simple; at other times it is not so readily and promptly done. We have found Treves's bloodless fold, a small peritoneal-covered fat fold running from the cecum upward on the antemesenteric border of the terminal ileum for a distance of 2 to 5 cm., to be of the greatest value in identification of the ileocecal region. Usually by gently pushing the coils of the small bowel to one side or the other, this fold can ultimately be seen, the segment of terminal ileum gently grasped, and the ileocecal valve positively identified. A loop of bowel is then brought out through the wound and protective moist pads placed beside the bowel. We prefer an end ileostomy to the double barrel ileostomy which we so commonly used in past years. We reserve the double barrel ileostomy for the acutely ill patient when we are desirous of doing an absolute minimum and returning the patient to the bed in the shortest possible period. Under these conditions, a loop of bowel is brought out through the wound, and a few fine cotton sutures are taken in the peritoneum and fascia. After making a small rent in the mesentery of the bowel a piece of skin is brought through this rent and the skin edges are carefully closed with a serum-proof suture, such as, dermalon.

Except for the occasional acutely ill patient, an end ileostomy is carried out. Clamps are placed across the bowel approximately 15 cm. proximal to the ileocecal valve (or proximal to gross abnormality of the ileum), and the bowel is divided with a cautery. The mesentery is divided about 5 cm. and the distal end is inverted with a double layer of #000 chromic catgut and a final layer of interrupted fine (#70) cotton. The distal end is then dropped back into the peritoneal cavity. If the stump is properly inverted, if its blood supply has not been jeopardized, and if there is no obstruction distal to the inversion, blowout of the stump will not occur. The proximal end is brought out through the wound with the clamp still in place. The peritoneum, fascia, and skin are then closed around the bowel. It is important that this closure be neither too snug nor too loose. Usually, if the opening through the abdominal wall is just snug to the index finger, it will prove adequate. If smaller than this, obstructive symptoms will frequently occur and jeopardize the convalescence; whereas, if much larger, a loop of bowel may prolapse out through the wound or the bowel itself may tend to extrude We choose to have the ileum approximately 2 cm. above the level of the skin.

Dragstedt has advocated the immediate application of a skin graft to the segment of ileum external to the skin. Our experience with this procedure has been too limited to recognize its possible merits fully. Grafts take promptly, but the

Miscellaneous

There are several other indications for colectomy. A few patients with chronic secondary anemia which would not respond to iron or to other treatment have been restored to health by removal of the diseased colon. Chronic infections of the skin which have failed to respond to treatment have healed promptly when the diseased colon has been removed. We have also advised colectomy in a few patients with a second chronic disease for which there was no specific treatment, such as minimal lesions of pulmonary tuberculosis and, more particularly, infectious arthritis Some, but not all, of the latter group have been markedly aided by the elimination of the diseased bowel.

INDICATIONS FOR PROCTECTOMY

The indications for proctectomy are quite definite. Following removal of the colon there should be very little discharge from the rectal stump. In many instances, the condition of the lower segment of the bowel is not incompatible with later use, and under these conditions we believe the bowel should not be removed as a part of a planned procedure. If, however, there is definite evidence of persistent activity in the stump shown by continued bloody discharge, particularly if in association with the rectal discharge there is extensive scarring and strictures, making examination of the upper limits of the segment impossible, the segment of bowel should then be removed by a combined abdominoperineal procedure

Local sepsis is also an occasional indication for removal of the stump. Perianal abscesses and fistulous openings will be eliminated only with extirpation of the bowel

TECHNIC OF OPERATION

Ileostomy

Ileostomy is not a difficult operation to perform Mortality following ileostomy, while much lower than in former years, remains high. If the ileostomy is properly done, the high mortality is the mortality of the disease and not of the operation. If, however, the operation is not done with great attention to all details, not only will the mortality for the disease remain high, but in addition to that, there will be a high mortality from the operation itself. With proper care this procedure can be carried out on almost any patient, no matter how ill, with little untoward reaction on the part of the patient. Except in rare instances, exploration contributes nothing to the future care of the patient It is hazardous, increases the risk of the ileostomy, and is, we believe, contraindicated.

Anesthesia. With but few exceptions we use a 1 per cent procaine block of the abdominal wall for anesthesia, adding enough sodium pentothal to the intravenous solution, usually 5 per cent dextrose in normal saline, to spare the patient any emotional shock and also to eliminate the discomforts associated with the injection of the procaine. It is important, we feel, to depend on the procaine for anesthesia and for relaxation of the abdominal wall, using the pentothal not as anesthesia but as analgesia.

In an effort to avoid manipulation as much as possible, we usually carry the dissection from the rectosigmoid region around the splenic flexure to about mid-transverse colon as the initial step without dividing the bowel. The posterior peritoneum is then carefully sutured so that when the small bowel is brought from the right side of the abdomen over to the left side, it need not be further disturbed at a later time. Mobilization of the splenic flexure, probably the most difficult part of the procedure, only rarely offers any real difficulties, providing the incision has been carried high enough. In certain instances where there is a great deal of reaction in the mesentery and in the surrounding fat, care must be taken not to tear the spleen. In carrying out the dissection, the vessels should be carefully clamped before they are divided. Usually a large strip of dry gauze placed in the retroperitoneal area during the course of the resection of the left colon will control the smaller oozing vessels which sometimes are present. It is important that they are controlled before the peritoneum is closed over them. There is little danger to important structures if the dissection is kept reasonably close to the bowel. Careless application of clamps might easily injure the duodenum in its first or second portion, but only if the proximity of this to the colon is not appreciated If a double barrel type of ileostomy has been done, a small blind segment of ileum, probably 5 cm. within the peritoneal cavity, will be left and the end turned in, care being taken not to jeopardize the blood supply either to the ileostomy itself or to this blind segment when the mesentery is divided. Whenever possible, we close the opening between the ileostomy and the lateral peritoneum in an effort to prevent the small bowel from herniating through this opening. For this purpose we use a #70 cotton suture. There is no standard mechanism of closing this opening because of the varying conditions present. In most instances, it can be satisfactorily accomplished. We have occasionally found it impossible to do.

The time of division of the bowel at the rectosigmoid area depends on the management of the stump. In those cases in which the bowel is too badly diseased to permit a safe inversion of the lower end, the bowel is brought out through the lower end of the wound and is not divided until the wound has been closed If the condition of the bowel is such that it would seem possible to turn in the end of the distal segment safely, the bowel is divided at or slightly above the level of the brim of the pelvis just before closure of the abdomen. The end of the bowel is carefully inverted, covered with fat tabs, and left inside the peritoneal cavity. The abdomen is closed without drainage and the colectomy wound carefully protected from possible contamination from the ileostomy discharge.

PROCTECTOMY

The rectum is removed by a combined abdominoperineal procedure, not unlike the Miles' approach for cancer of the rectum. If there is a draining sinus at the lower end of the colectomy wound, the abdomen is opened through the old incision above this. The incision is then carried around the rectal stump and the latter is capped by tying a square of rubber dam over the end.

In freeing the rectum from its attachments, the dissection is carried closer to the bowel than in the operation for cancer; otherwise the two operations are similar. We are particularly careful to keep close to the bowel during the perineal

rigidity resulting in the early postoperative period has caused varying degrees of obstruction in the few instances in which we have used it, necessitating removal of the graft. This procedure has proved satisfactory in other hands, however, and is not to be condemned on the limited experience which we have had.

We take no sutures in the bowel, no anchoring stitches being taken to fix the bowel in the wound or to the skin. Great care is taken to be sure that the skin edges are everted against the wall of the bowel and gauze squares are carefully placed around the exteriorized portion of the bowel to which the bowel promptly becomes adherent. The clamp is left in place when the patient leaves the operating room.

SUBTOTAL COLECTOMY

The removal of the colon has been approached by different surgeons from two somewhat different points of view. Cattell believes that once ileostomy has been done and colectomy is indicated, the total removal of the large bowel should be carried out in a planned two-stage procedure. In the first stage, the right colon and a portion of the left are removed, and in the second stage, the remainder of the left colon together with the rectum is removed in a combined abdomino-perineal procedure Because the left colon is usually most seriously involved and because the rectum can frequently be left without harm and with certain advantages to the patient, we prefer to remove the entire colon to the rectosigmoid region in our second stage.

An important preliminary measure is the preparation for subtotal colectomy in the passage of the Miller-Abbott or similar long intestinal tube. It is usually put down 36 to 48 hours before operation in an effort to deflate the small bowel and to have it fluted on this tube in such a manner as to minimize the intra-abdominal contents and also to make it possible to manipulate them easily with a minimum of trauma.

Incision With the ileostomy on the right, we prefer a long left paramedian incision. This extends from just above the pubes high enough in the epigastrium to permit ready mobilization of the splenic flexure.

Anesthesia. Our own preference is for nitrous oxide-oxygen-ether anesthesia, although we see no objection to the use of spinal anesthesia for those who prefer this for their abdominal surgery.

We have carried out the operation both from left to right and from right to left, and now do it routinely from left to right. Technically, it would seem to make little or no difference which way the dissection is carried out. Theoretically, there may be some advantage by beginning at the left in the more critically ill patients, since by this procedure that segment of the bowel which is most seriously involved will be freed and removed in the earlier part of operation, leaving the less involved segment to the last.

Because intestinal obstruction is too frequently seen as a late complication of subtotal colectomy, we make every effort to minimize the incidence of this complication. The omentum which we formerly preserved for whatever protection it might give was often found to be involved in a later obstruction, and it is now removed. We are also careful in reperitonealizing the root of the mesentery, leaving a smooth suture line which puts all of the knots in the extraperitoneal tissues

intravenously. Our present policy is to include 1 gm. of ascorbic acid, and the B complex in about the following amounts:

Thiamine hydrochloride	20 mg.
Riboflavin	6 mg.
Pyridoxine hydrochloride	6 mg.
Nicotinamide	40 cc.
Sodium pantothenate	6 mg.

Complications. The complications following ileostomy will be dependent on a number of factors. It is of greatest importance to avoid so far as possible all trauma to the distal ileum. Undue manipulation with catheters or other tubes may easily traumatize the bowel at the level of the peritoneum, fascia, or skin and result in fistulous openings at some level external to the peritoneum. This complication would be almost entirely avoided if great care were used in any manipulations within this distal segment of bowel.

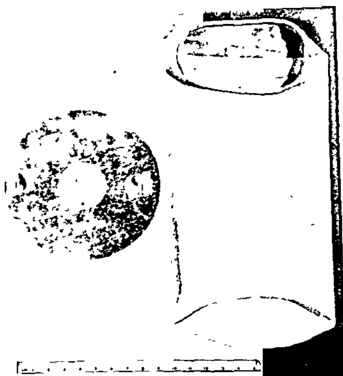


Fig. 1.—Temporary ileostomy outfit devised by Dr. Ferdinand Haase, consisting of two pieces of leather fastened to either side of a piece of copper with tabs projecting for attachment of an elastic belt. The bag is a filler for the Travellor colostomy outfit. The average lumen should be about 3.5 cm.

Obstruction at the outlet is commonly seen, frequently not promptly recognized and unless intensively treated, may be disastrous. This obstruction usually occurs at the advancing edge of the mucosa as it grows down over serosal covering of the ileum distal to the skin. This advancing edge is readily noted by inserting the finger into the ileostomy opening and may be recognized as a tight band. The earliest symptom of this complication is usually profuse watery discharge from ileostomy with rapid depletion of both sodium and chloride, the patient

part of the operation, hopeful that by so doing we may lessen the incidence of bladder and sexual (male) disorders which follow this procedure.

If the pelvic cavity is relatively dry after the rectum has been removed and if there is no perirectal sepsis, the wound is closed without drainage.

Colectomy and Proctectomy in One Stage

In selected cases the entire large bowel may be removed in one stage. The indications for so extensive a procedure must of necessity be limited. Possibly massive hemorrhage may be an indication when the source of the bleeding cannot be determined. Undoubtedly in certain of these cases the perineal dissection should be done first, or as suggested by Warren, a perineal team and an abdominal team may work simultaneously according to the method described by Dunphy.

Our own experience is limited to 2 cases, each of which was done in the usual manner, removing first the colon, then proceeding with the abdominoperineal removal of the rectum.

POSTOPERATIVE CARE AND COMPLICATIONS

Ileostomy

The clamp which has been applied to the ileostomy is removed after 24 hours. A soft catheter, about 22 French, is then gently passed into the ileum and fastened in place with a purse-string suture through the distal portion of the bowel. This is permitted to drain into a bottle Under ordinary conditions, this will continue to drain satisfactorily for a period of three or four days, after which time the ileal contents will become too solid to pass readily through the tube. When the consistency of the bowel contents has reached this stage, the tube is removed and a temporary ileostomy bag is then applied (Figs. 1 and 2). This is applied directly to the skin without regard to the wound and is held in place with skin cement * and an elastic belt. In the application of this bag great care must be taken that the opening through the base is adequate to permit the ileostomy to pass without undue constriction. Even then, the ileostomy must be carefully watched lest the bag ride up and cut into the lower portion of the bowel. This bag is usually satisfactory until a permanent type of bag is applied.

Fluids Fluid and electrolyte balance must be carefully followed. The loss through the ileostomy and by vomiting may be severe and must be replaced. A normal hemoglobin is maintained by free transfusions of whole blood. The total fluid intake will usually vary from 2500 to 4000 cc. daily. The amount to be given as 5 per cent dextrose in water or of 5 per cent dextrose in normal saline will depend on the salt need This will usually follow determinations of the serum level, of the chlorides and by following the chloride excretion in the urine as advocated by Evans.

Diet. The diet is varied, depending on the tolerance of the patient. It is not increased according to any definite schedule, but a smooth diet without roughage is permitted as soon as the patient will tolerate it.

Vitamins. Empirically, vitamins are used in one of the daily preparations given

* Manufactured by Dewey and Almy Chemical Company, Cambridge, Mass.

minimize this complication, all aimed at applying some protective covering to the wound and to the skin of the abdominal wall. None of these in our hands has been wholly successful, but careful application of the temporary ileostomy bag, followed by the application of the permanent appliance, has for practical purposes eliminated this complication.

Ileostomy Appliance. There is no universally accepted ileostomy appliance. Probably most patients have reasonable satisfaction from the so-called Rutzen bag, which is cemented to the abdominal wall and is made to fit each individual ileostomy. There are those, however, who will not tolerate the cement. There are others who by choice prefer some other type of appliance which is not cemented to the abdominal wall and which in many instances are home made. It is now our policy to measure and fit these patients with a Rutzen type of bag, and whenever possible, we find it helpful to have a patient who has been trained in the use of the ileostomy come in and talk with these patients prior to the latters' discharge from the hospital.

Colectomy

The postoperative care following subtotal colectomy is essentially that of any uncomplicated laparotomy The Miller-Abbott tube is removed in 24, 48, or 72 hours, depending on its tolerance by the patient. Fluids are permitted by mouth as soon as tolerated, and after 24 hours the patient is permitted an increasing diet according to his individual tolerance. Intravenous 5 per cent dextrose in distilled water with vitamins as previously mentioned is utilized to insure a total intake of from 2500 to 3500 cc. daily. Unless there has been some loss of fluids, we do not customarily give salt in the intravenous fluids until 24 or 48 hours have elapsed, providing that the patient has been in good electrolytic balance prior to the operation. The patient is permitted to be up and about any time after 24 hours. Antibiotics are not given routinely unless there has been some positive indication, such as local abscess or unexpected soiling.

Complications. Complications following subtotal colectomy are not specific to that procedure.

Proctectomy

The care following the combined abdominoperineal removal of the rectum is essentially that described above. In general, we keep these patients in bed a little longer because of the rather thin peritoneal floor which has been constructed, usually permitting them to get up at the end of five or six days. The catheter is left in place from five to seven days, then removed. If the patient voids satisfactorily, it is not replaced. If there is some uncertainty as to whether or not the patient has emptied the bladder, he should be catheterized directly after voiding to ascertain the amount of residual urine If he is unable to void, the catheter should be reinserted and permitted to remain in place for another period of four or five days. In other words, the management of the bladder is essentially the same as following any combined abdominoperineal procedure. As a rule this problem is not a major factor in this group of patients because they are younger and probably also because great care is taken to keep the dissection much closer to the bowel with possibly less disturbance to the nerves to the bladder.

quickly going into a state of profound collapse. The response to the intravenous injection of 5 per cent dextrose in saline in adequate amounts is prompt and gratifying. If the opening through the abdominal wall was adequate at the time the ileostomy was performed, it will remain adequate. The obstruction under these conditions will always be at the advancing edge and can be readily rem-



Fig. 2 —Attachment of the bag to the leather diaphragm. The rubber is stretched tight over the leather and cemented to the skin. The outfit is made by the Pharmacy at the Massachusetts General Hospital.

edied by several small incisions through this constriction, then gentle dilatation with the finger. Once these incisions have been made, the ileostomy should be, as

f the second week

10 days.

Skin Irritation: If the ileum is permitted to drain into an abdominal dressing, it may be extremely disturbing. A variety of methods has been used in an effort to

third had an exacerbation of her colitis and later died of a brain tumor. Two patients whose ileostomy was followed by subtotal colectomy had a re-anastomosis between the ileum and the rectum. The interval in one instance was seven years between the colectomy and the anastomosis, and this patient has done well. The interval in the second instance was five years, and this patient while well feels that he is somewhat more restricted in his activities because of the frequent loose movements than he was with his ileostomy.

Socio-economic Results

A careful follow-up study has been reported on 110 patients who survived ileostomy. Eighty-four per cent of the 104 patients who were living considered themselves to be in good health. Ninety-seven per cent were working as housewives, were in school, or were gainfully employed. In 23 of the 70 married patients, the ileostomy preceded marriage, five of the women have gone through one or more pregnancies subsequent to ileostomy.

Ileostomy in a patient who is otherwise well is entirely compatible with a productive and happy life.

REFERENCES

Cattell, R B Technic of Total Colectomy for Ulcerative Colitis. *S. Clin. North America*, 24.661, 1944

Cattell, R. B., and Boehme, E. J Importance of Malignant Degeneration as a Complication of Chronic Ulcerative Colitis *Gastroenterology*, 8 695, 1947.

Dennis, C · Personal communication

Dennis, C., et al.: The Response to Vagotomy in Idiopathic Ulcerative Colitis and Regional Enteritis *Ann. Surg*, 128 479, 1948

Dragstedt, L R, Dack, G. M., and Kirsner, J B.. Chronic Ulcerative Colitis; a Summary of Evidence Implicating *Bacterium necrophorum* as the Etiologic Agent. *Ann. Surg.*, 114 653, 1941

Dunphy, J E. Combined Perineal and Abdominal Operation for Repair of Rectal Prolapse. *Surg., Gynec. & Obst*, 86 493, 1948.

Jackman, R. J, Bargen, J A, and Helmholz, H F.. Life Histories of 95 Children with Chronic Ulcerative Colitis, Statistical Study Based on Comparison with Whole Group of 871 Patients *Am J Dis Child*, 59 459, 1940

Lynn, D H. Relationship of Chronic Lesions to Carcinoma of the Colon—Chronic Ulcerative Colitis, Collective Review *Internat Abstr Surg*, 81.269, 1945

McKittrick, L S, and Moore, F D Ulcerative Colitis. Ileostomy: Problem or Solution? *J A M A*, 139 201, 1949

McKittrick, L S, and Warren, R Use of the Miller-Abbott Tube in Subtotal Colectomy and Other Surgical Procedures *J A M A*, 117.345, 1941

Ravitch, M. M Anal Ileostomy with Sphincter Preservation in Patients Requiring Total Colectomy for Benign Conditions *Surgery*, 24.170, 1948.

Robbins, L L Personal communication

van Slyke, K K, and Evans, E I · The Significance of Urine Chlorides in the Determination and Treatment of Dehydration with Salt Depletion *Ann Surg*, 128 391, 1948.

Warren, R.. Personal communication.

If a drain has been inserted because of excessive bleeding, this is removed at the end of 24 or occasionally 48 hours. If a drain has been inserted because of infection, its management will depend on the local conditions and need not be taken up in detail here.

RESULTS

Hospital Mortality

In Table I are given the mortality figures following the surgical procedures. Mortality figures are of little value unless the individual cases are understood and the various factors entering into a fatal termination are given their proper consideration. Mortality of ileostomy done under the conditions previously set forth will probably always be high. Mortality, however, *should in most instances be* the mortality of the disease, not of the operation. It should be possible now to perform an ileostomy with a minimum of reaction to the patient and a maximum of safety if every detail is carefully followed through.

TABLE I

Patients with Ulcerative Colitis Admitted to Massachusetts General Hospital, 1932-1947 *

Operation	*Number of Cases*	*Deaths* *	*Mortality Percentage*
No operation	229	12	5.0
Ileostomy	149	22	14.8
Subtotal colectomy	90	6	6.7
Proctectomy	37	1	2.7
Restitution of continuity	5	0	0.0
Total cases	378	41	10.8

* Table includes all operations performed on this group up to Jan. 1, 1950.

The mortality for colectomy when it is done as an elective procedure should be low. The mortality for colectomy which is necessary because of progressive disease will be high, and when colectomy is carried out, as it has been in certain of our cases, in a desperate effort to salvage a life, the mortality will be very high. On the other hand, removal of a badly diseased bowel, even in a desperately sick patient, will many times be rewarded by a striking response and a complete return to good health. Proctectomy in this group is a relatively safe procedure and should carry a low mortality.

Late Results

Restitution of Continuity. The number of patients who may have successful restitution of continuity of bowel will depend largely on the indications for which the ileostomy was done. If the ileostomy is done early, a good many of those may have continuity restored at some later period. On the other hand, it is probable that those for whom continuity may be restored might well have never needed an ileostomy and probably, according to our indication, would not have had it done. Using the indications which we have used, we have attempted to restore continuity in only 5 instances. Three of these had been in excellent health and had had no symptoms referable to the bowel for a varying period of years. One of these 3 was successful; 2 have had to have the ileostomy re-established; the

third had an exacerbation of her colitis and later died of a brain tumor. Two patients whose ileostomy was followed by subtotal colectomy had a re-anastomosis between the ileum and the rectum. The interval in one instance was seven years between the colectomy and the anastomosis, and this patient has done well. The interval in the second instance was five years, and this patient while well feels that he is somewhat more restricted in his activities because of the frequent loose movements than he was with his ileostomy.

Socio-economic Results

A careful follow-up study has been reported on 110 patients who survived ileostomy. Eighty-four per cent of the 104 patients who were living considered themselves to be in good health. Ninety-seven per cent were working as housewives, were in school, or were gainfully employed. In 23 of the 70 married patients, the ileostomy preceded marriage, five of the women have gone through one or more pregnancies subsequent to ileostomy.

Ileostomy in a patient who is otherwise well is entirely compatible with a productive and happy life.

REFERENCES

Cattell, R. B. Technic of Total Colectomy for Ulcerative Colitis. *S. Clin. North America*, 24 661, 1944.

Cattell, R. B., and Boehme, E. J Importance of Malignant Degeneration as a Complication of Chronic Ulcerative Colitis. *Gastroenterology, 8* 695, 1947.

Dennis, C., Personal communication.

Dennis, C., et al.: The Response to Vagotomy in Idiopathic Ulcerative Colitis and Regional Enteritis *Ann Surg*, *128*.479, 1948.

Dragstedt, L R, Dack, G. M, and Kirsner, J. B. Chronic Ulcerative Colitis, a Summary of Evidence Implicating *Bacterium necrophorum* as the Etiologic Agent. *Ann. Surg*, *114*:653, 1941.

Dunphy, J. E., Combined Perineal and Abdominal Operation for Repair of Rectal Prolapse. *Surg, Gynec & Obst., 86* 493, 1948

Jackman, R. J., Bargen, J A., and Helmholz, H. F: Life Histories of 95 Children with Chronic Ulcerative Colitis; Statistical Study Based on Comparison with Whole Group of 871 Patients *Am J. Dis Child*, 59.459, 1940

Lynn, D H Relationship of Chronic Lesions to Carcinoma of the Colon—Chronic Ulcerative Colitis; Collective Review. *Internat Abstr Surg*, *81*:269, 1945.

McKittrick, L. S, and Moore, F D., Ulcerative Colitis. Ileostomy. Problem or Solution? *J A M A.*, *139* 201, 1949.

McKittrick, L. S, and Warren, R.: Use of the Miller-Abbott Tube in Subtotal Colectomy and Other Surgical Procedures. *J.A.M.A.*, *117* 345, 1941.

Ravitch, M M. Anal Ileostomy with Sphincter Preservation in Patients Requiring Total Colectomy for Benign Conditions *Surgery*, *24*.170, 1948.

Robbins, L. L. Personal communication.

van Slyke, K. K, and Evans, E I. The Significance of Urine Chlorides in the Determination and Treatment of Dehydration with Salt Depletion. *Ann. Surg.*, *128*:391, 1948.

Warren, R., Personal communication.

The Cytologic Diagnosis of Cancer

PETER A. HERBUT, M.D., AND ABRAHAM E. RAKOFF, M.D.

HISTORY

THE DIAGNOSIS OF CARCINOMA by cytologic methods is an old practice that dates almost to the middle of the nineteenth century. According to Zemansky, the first positive diagnosis of cancer from an examination of any body fluid was made by Beale in 1860 when he recognized single and clumped neoplastic cells in unstained smears of sputum from a case with carcinoma of the pharynx. In 1869 Ashworth discovered neoplastic cells in the blood stream of a patient with cutaneous carcinomatosis. In 1876 Hampeln isolated sarcomatous cells in smears of sputum from a patient who previously had an extremity amputated for sarcoma. In 1882 Quincke found neoplastic cells in smears of ascitic fluid removed from a patient who was thought clinically to have cirrhosis of the liver. His diagnosis of abdominal carcinomatosis was later substantiated at necropsy. Also in 1882, after introducing new fixing and staining methods for smears of blood and exudate, Ehrlich made a diagnosis of abdominal carcinomatosis in 3 cases from an examination of ascitic fluid. Neoplastic cells in sputum in a case of sarcoma of the lungs were reported on in 1890 by Huber. In 1893 Prentiss discovered tumor tissue in smears of fluid removed from the pleural cavity

In 1895 three contributions on the subject are worthy of note. Rieder demonstrated mitoses in smears of ascitic fluid from a case of carcinoma of the ovary. Bahrenberg maintained that fresh and dried smears either stained or unstained were inadequate in making a diagnosis of carcinoma and, therefore, introduced a method of sectioning a mass of sedimented cells. According to him, it was preferable to allow the fluid to stand and clot spontaneously, to pour off the supernatant portion, to harden the remains by adding alcohol, to embed the small stringy mass in celloidin, and to treat this material as though it were a piece of tissue. Betschart found atypical cells in stained smears of both sputum and ascitic fluid. Two years later, in 1897, Dock, studying stained smears of both pleural and ascitic fluid, concentrated on the difference between neoplastic and non-neoplastic cells. In the same year Warthin demonstrated spindle cells in smears of thoracic fluid removed from a case of fibrosarcoma of the pleura, while a year later Benecke discovered pigmented cells in smears of ascitic fluid obtained from a case of melanosarcoma.

In 1900 Mandlebaum, apparently unaware of Bahrenberg's publication five years previously, described a method of sectioning sedimented fluid which was widely used in this country and abroad for decades to follow. His method consisted of allowing large amounts of fluid to sediment, decanting the supernatant fluid, centrifuging the sediment in a tapered centrifuge tube, fixing the plug of

cells in formalin, and treating the agglutinated cells as one would treat a piece of tissue.

In the first decade of the twentieth century there were at least 17 papers published on the subject of cytologic diagnosis of carcinoma. In five of these emphasis was laid on the presence of mitoses, while in the others irregularities in shape, size, and staining qualities of the cells were stressed. In 1911 Warren presented 5 cases in which the diagnosis was made from stained smears. He observed that mitoses were rarely found even in those cancer cells which were present in the fluid. In 1917 Mandlebaum again described the method that he had first reported 17 years previously. Five years later Panton was able to demonstrate sarcoma cells in smears of cerebral spinal fluid. In 1924 Seecof and Boetch presented a series of cases that had been examined by the embedding technic. They reported that a positive diagnosis was attended by a high degree of accuracy, whereas a negative diagnosis meant nothing. They also commented on the difficulty of differentiating mesothelial cells from neoplastic cells. In 1928 Zemansky reported his experiences in the examination of almost 1,000 fluids and secretions His positive reports were 87 per cent accurate.

In recent years intensive study has been made of smears of vaginal secretions. It has been known for a long time that the superficial epithelium of the vagina sheds cells which reflect the function of the ovaries if prepared by proper cytologic methods. It was during the course of such studies that Papanicolaou more than two decades ago *noted the presence of unusual cells in vaginal smear preparations* which on further investigation appeared to be shed from a malignant lesion of the cervix. It was not until 1943, however, when Papanicolaou and Traut published their classic monograph, *Diagnosis of Uterine Cancer by the Vaginal Smear,* that widespread interest was aroused in the possibility of employing vaginal cytologic preparations for the diagnosis of uterine cancer. The value of this technic has now been amply confirmed and it has taken its place as a routine diagnostic procedure in laboratories throughout the world. It was recognized early, and emphasized by Papanicolaou himself, that the method was not an infallible one and that it was not nearly as easy to interpret the test as it might seem to the uninitiated. Despite such warnings (Scheffey and Rakoff), however, the lay press saw fit to publicize the method as an easy, rapid procedure for discovering uterine cancer in women and intimated that it could be carried out by any physician anywhere. More unfortunate, perhaps, has been the fact that physicians and even technicians, untrained in the technic, undertook the responsibility of making diagnoses of cancer and even carrying out surgical procedures on the basis of their results, with unfortunate consequences in some cases. Nevertheless, as increasing numbers of pathologists have acquired adequate training and experience with the method, vaginal cytology has found a place of real value among our diagnostic procedures. Although there have been a few modifications in technic suggested, such as the inclusion of smears from the cervix as well as from the vagina and suggested changes in staining technics by some groups, the method and its interpretation remain essentially unaltered from that described by Papanicolaou and Traut in their monograph. In this presentation our experiences covering a period of six years are only summarized. Those who wish additional background in detail should consult the monographs by

Papanicolaou and Traut, Papanicolaou, Marchetti, and Traut, and Gates and Warren. For those, however, who wish to become sufficiently versed in this method to employ it as a diagnostic procedure, it is recommended that they seek training in the laboratories of those experienced in the technic. Currently, the American Cancer Society offers a four month course for pathologists in various qualified laboratories throughout the country.

Following the publications of Mandlebaum, Seecof, and Boetch, and Zemansky most laboratories used the paraffin embedding technic in the examination of body fluids and secretions for neoplastic cells Since the more recent work of Papanicolaou and Traut and others, however, the pendulum has again swung in the opposite direction and at the present time smears of secretions or sediment, stained by the Papanicolaou technic, have become quite popular and are being employed with a high degree of accuracy. Because the method varies slightly from laboratory to laboratory it is our purpose in this presentation (1) to describe precisely the procedure which we use in preparing and staining smears, and (2) to consider under separate headings the systems and organs from which these materials are obtained To accomplish the latter we shall state the exact method of collecting the material, describe the appearance of normal and abnormal cells from the respective locations, present our own experiences and results, and compare these with the method and results of other workers in the respective fields

METHOD

Inasmuch as the methods of collecting the material from different regions of the body vary they will be discussed separately under the respective headings. Once the fluid or secretions are obtained in suitable form thin smears are prepared on ordinary 1 × 3 inch slides. The exact technic of preparing the smears and the number of slides used in a given case vary from observer to observer. In regions of the body other than the female genital system it is our routine to make six smears from each specimen. Regardless of the source of the fluid, a drop or two of properly prepared fresh material is deposited on the surface of each of three clean, preferably new, slides. Each drop is then covered with a separate slide. With compression and a to and fro movement of the top slide the material is spread thinly over both apposing surfaces, so that ultimately the film is no thicker than that ordinarily obtained in preparing a smear of peripheral blood. The smears, while still wet, are then immediately immersed in a fixative composed of equal parts of 95 per cent alcohol and ether. Here they remain for five to 10 minutes or longer, after which they are stained by the regular Papanicolaou technic. If, for some reason or other, staining cannot be carried out immediately the slides may be removed from the fixative, allowed to dry at room temperature, and be stained any time thereafter. Likewise, if it is desirable to send material by mail we have found it preferable to prepare the smears in the manner indicated, to allow them to dry, and to send them in the dried state without the addition of glycerin or any other preservative. In such cases, if the material is properly collected and the smears carefully prepared, the ultimate results will be just as good as if staining is carried out immediately.

Notwithstanding the fact that we use, and have not modified, Papanicolaou's technic, it should be pointed out that there is nothing magic or specific about this stain. It does not pick out, for example, neoplastic cells to the exclusion of other cells. It does, however, offer certain advantages over other methods: (1) it preserves and stains the structural details of a cell with a clarity that, in our opinion, cannot be duplicated by any other method, (2) it differentiates certain sloughed epithelial cells according to the degree of glycogen content and is, therefore, important in gynecologic work, and (3) it differentiates keratinized squamous epithelial cells from other more primitive or highly specialized cells and is thus of considerable value in studying smears of, for example, bronchial secretions Other workers, however, use a variety of stains, such as hematoxylin and eosin, Giemsa's stain, and Wright's stain, and as far as the diagnosis of carcinoma is concerned they obtain equally good results. In other words, the most important factors are the assiduousness, astuteness, and experience of the examiner rather than the type of dye which is employed.

Although the various stains employed in the Papanicolaou method can be purchased commercially, they may be prepared with ease in any laboratory. For the sake of convenience the following details are therefore offered. Stains EA 36 or EA 50 are equally effective. Stain EA 36 consists of 45 cc. of a 0.5 per cent solution in 95 per cent alcohol of light green SF yellowish, 10 cc. of a 0 5 per cent solution in 95 per cent alcohol of Bismarck brown, 45 cc. of a 0.5 per cent solution of 95 per cent alcohol of eosin yellowish, 0 2 gm. of phosphotungstic acid, and 1 drop of a saturated aqueous solution of lithium carbonate. Each of the 0 5 per cent alcoholic solutions is prepared by heating, and then they are simply combined and kept in stock without filtering. Stain OG 6 consists of 0 025 gm. of phosphotungstic acid added to 100 cc. of a 0 5 per cent solution of orange G in 95 per cent alcohol. For staining purposes these and the other necessary solutions are conveniently placed in ordinary Coplin jars. The steps in the staining may be outlined as follows: (1) smears are rinsed in 70 per cent and then in 50 per cent alcohol and finally distilled water, (2) they are immersed in Harris' hematoxylin for five to 10 minutes, rinsed in distilled water, rinsed three to four times in 0 5 per cent aqueous solution of hydrochloric acid, rinsed thoroughly in water, differentiated for one minute in a solution of lithium carbonate composed of 3 drops of saturated aqueous solution per 100 cc. of water, and rinsed thoroughly in water, (3) slides are then rinsed in distilled water, 50 per cent alcohol, 70 per cent alcohol, 80 per cent alcohol, and 90 per cent alcohol; (4) they are stained for one minute in OG 6; (5) rinsed five to 10 times in each of two jars containing 90 per cent alcohol in order to remove excess stain; (6) stained in EA 36 or EA 50 for two minutes, rinsed five to 10 times in each of three jars containing 95 per cent alcohol, rinsed in absolute alcohol, cleared in xylol for five to 10 minutes, and mounted in Canada balsam.

The smears are then examined systematically in a crisscross manner so that every portion of every slide is scanned. Although the magnifications used in examining the smears vary from observer to observer, we have found it convenient to do preliminary scanning with 80 to 100 magnification and detailed study with 400 magnification. It is not necessary to use oil immersion

CANCER OF THE FEMALE GENITAL TRACT

Collection of Material

Smears for cytologic study may be prepared from one or more of the following sites: (1) the vagina, (2) the ectocervix, (3) the endocervix, (4) directly from the surface of any suspicious lesions, (5) from the uterine cavity. The types of smears to be taken depend somewhat on the problems in the individual case, since there are certain advantages and disadvantages for each (*Table I*).

TABLE I

Collection of Smears

Sources	*Technic*	*Advantages*	*Limitations and Disadvantages*
Vaginal	Aspiration with pipette from posterior fornix	Simple and convenient, contains cells from entire genital tract; best for determining ovarian function	High proportion of vaginal cells; relatively few from cervix and endometrium
Endocervical	Aspiration with pipette from cervical canal	High proportion of cervical and endometrial cells	May miss cells from lesions on ectocervix
Cervical Scrapings	Scraping of cervix with spatula	Cells obtained directly from most commonly affected area of cervix	Does not contain cells from other area of cervix or endometrium
Lesion	Scraping or aspiration from lesion visualized on cervix or vagina	Cells obtained directly from lesion in question	Cells from only one area; should not replace biopsy

Note Endometrial smears have also been suggested but are not recommended for routine purposes because of potential dangers in invading uterine cavity

For routine screening purposes, some workers still take smears from the vagina alone but more commonly smears are taken from the vagina and from the endocervix. The posterior fornix of the vagina is a natural reservoir for secretion and desquamated cells from all parts of the genital tract including the fallopian tubes, endometrium, and the cervix and vagina. For this reason smears collected by aspiration of secretion from this site are most likely to be representative and in addition are the easiest and most convenient to prepare. Furthermore, vaginal smears are the most satisfactory for providing information concerning ovarian function. On the other hand, such smears tend to contain a high proportion of cells from the vagina with but relatively few from the cervix and endometrium, whereas smears made from the endocervical secretion will be rich in cells from the upper genital tract. Since smears prepared from the endocervical mucus may not contain cells from lesions of the ectocervix, a third smear may be prepared by scraping the ectocervix with a spatula; the latter will contain a high proportion of cells from the junction of the squamous epithelium of the vagina and the columnar epithelium of the cervix which is the most common site of origin of cervical carcinoma. Smears of cervical scrapings are of course not usually satisfactory for the detection of cancer of the endometrium or fallopian tubes. If on

speculum examination a lesion should be apparent either in the vagina or cervix it is good policy to prepare an additional smear by scraping the surface of the lesion with a spatula

For general routine screening purposes it has been our practice to collect one smear from the posterior fornix of the vagina and another from the endocervix. If on speculum examination, there is an erosion or any other lesion of the cervix a third smear is prepared from the cervical scrapings and an additional smear from any discrete lesion if one should be apparent.

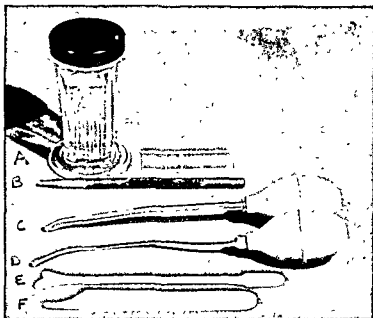


Fig 1 —Equipment for making vaginal and cervical smears (A) Coplin jar with screw-top and glass top, (B) diamond marking pencil, (C) slightly curved glass pipette with rubber bulb, (D) laryngeal cannula with rubber bulb, (E) Ayre scraper, (F) scraper cut from ordinary tongue depressor

Smears prepared from the endometrial cavity have been suggested as having the advantage of providing a high concentration of cells directly from the endometrial cavity Such smears, however, are not recommended for routine purposes because of the potential dangers inherent in invading the uterine cavity. In special instances if the patient and the examiner are properly prepared endometrial smears can be taken for additional study.

Technic It is preferable that the patient should not douche for at least 24 hours before smears are collected This is especially important if vaginal smears alone are to be taken If the patient has douched then it becomes especially important that endocervical smears and cervical scraping smears should be taken in addition to the vaginal smears.

The equipment which is necessary for routine purposes is as follows (Fig 1):

(1) Coplin jars with screw tops or similar jars for holding the slides.

(2) Fixative consisting of equal parts of ether and 95 per cent alcohol.

(3) Glass pipettes about 6 in in length and ¼ in in diameter with rounded

tip and narrow opening to which may be attached a strong rubber bulb for producing suction.

(4) A glass marking pencil with which the patient's name may be written on the slide.

(5) Wooden spatulas for taking cervical scrapings. These may be purchased or may be prepared by cutting a tongue depressor with a heavy scissors to fit the cervical canal The latter may be cut especially to fit the individual cervix.

(6) A metal laryngeal cannula is useful in those instances in which the cervical canal is narrow and will not accommodate the glass pipette. The laryngeal cannula may also be employed for preparing endometrial smears.

Vaginal Smears: Vaginal smears are best collected with the patient in the lithotomy position. With the bulb compressed, the glass pipette is introduced slowly, well into the posterior fornix of the vagina. It is not necessary to use the speculum nor should any lubricant be employed. The secretion in the posterior fornix of the vagina is aspirated by slowly moving the tip of the pipette from side to side as the pressure on the bulb is slowly released. After the pipette has been withdrawn the secretion is blown on to a glass slide near one end. The material then is spread with the outer surface of the pipette toward the opposite end of the slide to produce a moderately thin film. Before any drying can occur it is dropped into the jar of fixative.

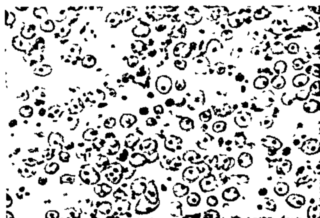
Endocervical Smears: With the patient in the lithotomy position the cervix is exposed with a bivalve vaginal speculum using as little lubricant as possible. If there is excessive vaginal secretion covering the ectocervix this may be gently wiped away with a dry cotton pledget. The secretion from the cervical canal is then aspirated with a glass pipette or a laryngeal cannula. If an adequate amount of secretion cannot be obtained a satisfactory smear can be prepared by introducing a cotton-tipped applicator well into the cervical canal and rolling the secretion thus obtained onto the glass slide

Smears from Cervical Scrapings: After the cervix has been exposed with a speculum, the tip of the wooden spatula is introduced into the cervical canal so that the concave surface fits snugly against the adjacent ectocervix and endocervix (Ayre) The spatula is then rotated once or twice through the entire circumference of the cervix. The material on the spatula is then transferred to a glass slide and spread to make a film. The slide is dropped into a bottle of fixative at once.

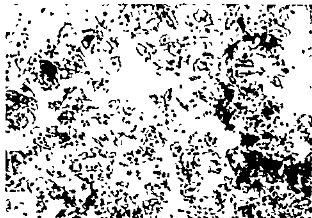
Smears from Lesions: Smears from the surface of lesions may be prepared by scraping the surface with a spatula or by aspirating the surface with a glass pipette or laryngeal cannula.

Endometrial Smears. As previously indicated this type of smear should be prepared only under special circumstances It must be ascertained that the patient is not pregnant and sterile precautions must be observed similar to those for endometrial biopsy or curettage. A sterile sound may be gently passed beyond the internal os This is then followed with a sterile laryngeal cannula and secretion gently aspirated with a rubber bulb or syringe, making every effort to rotate the tip of the cannula into all portions of the uterine cavity.

All smears are fixed immediately in equal parts of 95 per cent alcohol and ether, and stained according to the technic already outlined.



A



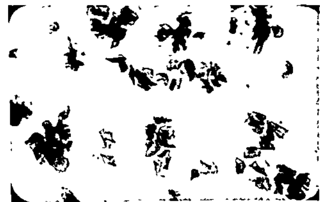
B



C



D



E



F

Caption on opposite page.

NON-NEOPLASTIC CELLS

The difficulties in the detection of abnormal cells in vaginal smears are largely due to the fact that there is a great variety of normal cells which may be found in the vaginal secretion, as well as many variations in those associated with benign conditions. Not only may there be cells present from all portions of the genital tract, from the fallopian tubes to the vagina, but the characteristics of these cells may change depending on the degree of ovarian function present. As a preliminary to mastering the cytologic technic for the detection of carcinoma, it therefore becomes necessary to be thoroughly familiar with the various types of normal cells which may be encountered and the interpretation of cyclic alterations.

Normal Vaginal Cells. The vaginal epithelium of the mature woman consists of three distinct layers which may be referred to as (1) a basal layer, (2) an intermediate layer, and (3) a superficial or functional layer. The degree of development of the vaginal epithelium is dependent on the ovarian hormones, particularly the estrogens, so that gross changes in ovarian function in different phases of life are readily reflected in the histologic appearance of the vaginal mucosa (Rakoff, Feo, and Goldstein).

Similar indication of ovarian function can be obtained from cytologic study of the cells shed from the vaginal mucosa as seen in smears Cells arising from the basal layer are of the small round or oval type, with relatively large nuclei. The cells of the intermediate layer are of the transitional variety but gradually become larger and flatter until they approach the true squamous type seen in the superficial layer. In the latter layer the degree of estrogen and progesterone effect is further indicated by more subtle cytologic changes and especially by the staining reaction of the cytoplasm The varying degrees of estrogen deficiency and effect can be outlined as follows (Rakoff, and Rubenstein) (Fig. 2).

(1) Marked Estrogen Deficiency All of the cells are of the basal type. Many of the cells may show hyperchromatic nuclei or mitotic activity. Leukocytes are numerous and often markedly excessive because of an associated atrophic vaginitis In the presence of an inflammatory reaction some of the basal layer cells which usually stain basophilic may be acidophilic in reaction. This type of smear may occur in castrates or in some postmenopausal women.

(2) Moderate Estrogen Deficiency: The majority of cells are from the basal layers but there are also some cells from the intermediate layer or even an occasional squamous cell of basophilic staining reaction. Leukocytes are present in varying numbers and mucus is plentiful.

FIG. 2 – Showing various degrees of estrogen deficiency in effect. (A) Marked estrogen deficiency as indicated by small, round cells from the basal layer of the vagina. (B) Slight estrogen deficiency as indicated by presence of cells from the basal layer of the vagina plus squamous cells from the intermediate and superficial layers. (C) Slight estrogen effect as shown by the presence of precornified cells with basophilic staining from the superficial layer. (D) Good estrogen effect as indicated by clumps of cornified and precornified cells from the superficial epithelial layer with acidophilic cytoplasm and pyknotic nuclei. (E) Good estrogen effect with regressive changes as seen in the corpus luteum phase indicated by cornified cells with an acidophilic cytoplasm many of which show characteristic folding. (F) Smear in pregnancy showing the characteristic twisted navicular cells or "pregnancy" cells due to marked shedding and desquamation of cells of the superficial layer.

(3) Slight Estrogen Deficiency: The majority of cells are from the intermediate layer with some from both the basal layer and the superficial layer. There are usually moderate numbers of leukocytes and some mucus.

(4) Minimal Estrogen Deficiency: Most of the cells are from the intermediate vaginal layer with some superficial cells of basophilic staining.

(5) Slight Estrogen Effect: The cells present are from the superficial vaginal layer. The cytoplasm stains basophilic, many of the nuclei are vesicular but some are dense. There are occasional leukocytes and mucus. This is the type of smear usually seen in the postmenstrual and early follicular phases.

(6) Moderate Estrogen Effect The majority of cells are of basophilic staining but some may take an intermediate stain and a few are acidophilic. This type of smear is normally seen in the late follicular and preovulative phases.

(7) Moderate Estrogen Effect. Almost all of the cells are acidophilic, some *markedly so In many of the cells the nuclei are small and dense or fragmented,* and some of the cells are completely cornified. The smear is often quite clear of leukocytes or mucus This type of smear is seen in the ovulative phase or in patients receiving full estrogenic therapy

(8) Estrogen Effect with Regression: When the peak of unopposed estrogen effect has passed, there is a tendency for the cells to become folded, to lose their bright acidophilic staining, and often to undergo cytolysis or mucification. This change may occur either because of the withdrawal of estrogenic hormone or because of the presence of progesterone which opposes the estrogen effect. During the corpus luteum phase the regressive changes continue in a regular fashion until just before menstruation when the estrogen effect is slight and regression quite marked

Pregnancy During normal pregnancy the vaginal epithelium which is being subjected to large amounts of both estrogen and progesterone shows a rather rapid and marked desquamation of the superficial vaginal layer. The large squamous cells are both of the basophilic and acidophilic type and not only tend to show folding but frequently marked twisting so that the cells assume a rather characteristic navicular shape The latter are sometimes referred to as pregnancy cells The nucleus is relatively large and the cytoplasm frequently contains dark granules Although the presence of these cells is not characteristic of pregnancy, they are noted in such large numbers in pregnant women as to arouse suspicion of pregnancy whenever they are seen

Ectocervix That portion of cervix which protrudes into the vagina is spoken of as the ectocervix It is covered by a continuation of the vaginal epithelium up to the point of the external os where there is a sudden change from the squamous epithelium of the ectocervix to the columnar epithelium of the endocervix This point of transition, easily recognizable because of the abrupt change in color from the pale pink of the squamous epithelium to the orange-red of the columnar epithelium, is an area of great importance since at this point many cervical carcinomas arise

The cells of the ectocervix closely resemble those from the vagina proper but can be distinguished by several characteristics. They are generally more round or ovoid than those from the superficial or intermediate vaginal layers and are almost always more basophilic in reaction, usually taking a somewhat brighter

n stain than the vaginal cells. The cytoplasm is frequently vacuolated and e is a rather heavy border about the periphery. The nucleus which is usually id or oval is, as a rule, eccentrically situated. If there is much cervical mucus ent the cells may assume a variety of colors from green to orange or purple.

ndocervical Cells Endocervical cells are readily distinguishable from those he ectocervix or vagina but not infrequently may closely resemble those of ometrial origin. Several types of endocervical cells may be distinguished. ietimes they may appear as typical columnar cells such as one sees on histo-c section lining the surface of the endocervical glands and may contain ying amounts of mucoid material. They tend to be rather square at one end may show cilia at this surface while the opposite end tends to taper. In other ances the endocervical cells are ovoid in shape and contain large vesicular lei. Cells of this type, because of their size and staining reaction, frequently emble those of endometrial origin. They are generally somewhat larger than se from the endometrium and the cytoplasm is more plentiful; they are bably derived from the lining surface of the endocervix. A third type of ocervical cell is sometimes referred to as the cervical mucus cell. It represents s from the cervical glands which have become mucified and have been shed the cervical mucus They are found in clumps and are readily recognized by ir large, evenly staining nuclei in a background of blue-staining mucus in ich the cell margins are indistinct or have vanished.

Endometrial Cells. Endometrial cells are the smallest of the epithelial cells mally found on the vaginal smear. They are round or ovoid with only a small, gular border of cytoplasm surrounding the nucleus. This cell varies some-at in size, shape, and appearance at different times of the cycle, and in the retory phase it appears somewhat larger and more ovoid in shape. The nucleus quite vesicular but has a rather dense blue-black membrane with dark-staining omatin granules distributed throughout. The cytoplasm stains rather faintly, ially a light blue. Endometrial cells are found in clumps just before, during, d after the menstrual period. In the interval phases the number of endometrial ls found in the vaginal smear is scant.

Histiocytes. Histiocytes of several types may be found in vaginal smears par-ularly in the presence of an inflammatory reaction.

Small histiocytes are about the size of endometrial cells and resemble these ute markedly. The nuclear margin, however, is less prominent and the cyto-asm demonstrates a fine, lacy pattern. In addition they generally occur in long egular chains in a rather characteristic pattern.

Large histiocytes demonstrate a marked degree of polymorphism. The nucleus generally deep-staining and dense and is usually oval or biscuit-shaped Not frequently it is fragmented giving the appearance of a series of buttons The toplasm is usually basophilic but can stain almost any color. Phagocytized lls or pigment are not infrequently seen in these macrophages.

EOPLASTIC CELLS

It is important to recognize at the onset that there is no single criterion for e detection of cancer which is applicable to all cytologic smears. On the con-ary, the diagnosis must be made from the evaluation of numerous factors. It is

for this reason that it is frequently impossible to make an absolute diagnosis of carcinoma Many workers have, therefore, adopted the policy of grading smears such as "grade 1" to "grade 5," to indicate that there is a greater or lesser probability of malignancy or of classifying them as "positive," "suspicious," "doubtful," or "negative." On the other hand, as experience is gained the cytologist is able to obtain a fairly high degree of accuracy by considering various factors, each of which by itself may not be sufficient to establish a diagnosis but which when considered together make a pattern which can be evaluated.

Nuclear Changes. Abnormalities of the nucleus are of far greater significance than changes in the cytoplasm so far as the recognition of neoplastic cells is concerned The more important variations are as follows:

(1) Anisonucleosis: Marked variation in the size of the nucleus as compared to the nuclei of normal cells from the same site, is perhaps the most common and most significant abnormality noted. The nuclei of cancer cells are not only unequal in size but generally are considerably larger than those of normal cells. This variation in size of nuclei is particularly evident in squamous cell carcinomas of the cervix. In endometrial carcinoma the nuclei are slightly but definitely larger than normal but tend to show less extremes in variation of size.

(2) Nuclear Deformities: Abnormalities in the shape and form of the nucleus constitute one of the most readily recognizable features of cancer cells. Such nuclei may be lobulated, may be irregular in shape, may be fragmented, or may assume various bizarre forms.

(3) Hyperchromatism: Abnormal cells can frequently be "spotted" even under low magnification by the dark-staining qualities of their nuclei. In some instances the entire nucleus may be deeply stained, obscuring its internal structure, while in other cases there may be more intense staining of the chromatin granules often with an increase of the size and clumping of the granules. In some instances the granules may collect around the nuclear border, causing this structure to appear thickened.

(4) Enlargement of the Nucleolus. Although not seen regularly, when enlargement of the nucleolus is present in a significant number of the cells it constitutes an important diagnostic feature, particularly if there is a marked change in the nuclear-nucleolar ratio as compared to that of similar normal cells In some instances there are also multiple nucleoli present which add further significance

(5) Mitoses. The presence of mitotic figures has less significance in cytologic diagnosis than it does in histologic evaluation, although mitoses are found in many neoplastic cells particularly those of ectocervical origin They may also be found in a high percentage of basal cells of vaginal or cervical origin.

(6) Multinucleated Forms: Multiple nuclei are not uncommonly found in some cancerous cells but again may also be present in cells from the basal layer of the vagina or cervix. In the abnormal cells, however, the nuclei are more likely to be unequal and distorted, whereas in the normal cell the morphology is more typical

Changes in the Cytoplasm. Changes in the cytoplasm are not nearly so specific as those in the nuclei and may occur in many conditions such as inflammatory lesions, benign neoplasms, and following irradiation. However, certain types of

cytoplasmic alterations are so commonly seen in malignant cells that their presence permits more ready detection of cells for further study and evaluation.

(1) Anisocytosis. Malignant cells are frequently larger than normal cells and sometimes quite markedly so. Another important feature is the fact that the increase in the size of the cell is often not in proportion to the increase in the size of the nucleus so that there may be considerable variation in the nuclear-cytoplasmic ratio.

(2) Polymorphism: A varying proportion of cancer cells shows abnormality in shape and form. This is more marked in squamous cell carcinomas than in adenocarcinomas. Although great individual variation is the rule, certain general morphologic patterns tend to accompany specific types of cancer. Thus in well differentiated squamous cell carcinomas of the cervix variants of the "tadpole" type (Plate I, A) are common while prickle forms are more common in the more poorly differentiated types. In spindle cell carcinoma fiber-like cells may be found, whereas in adenocarcinoma of the cervical canal the cells are more likely to be of the round type. In some instances giant forms or syncytial collections may be present.

(3) Abnormalities in Staining Reaction: Cancer cells quite regularly show some abnormality in the staining reaction of the cytoplasm but this factor alone is considered to be relatively unimportant since it may be found frequently in the presence of inflammatory reactions or following irradiation.

(4) Vacuolization: Another nonspecific finding seen not infrequently in cancer cells, is the increased vacuolization of the cytoplasm.

Other Factors Arousing Suspicion of Cancer. In addition to the specific cellular changes described above, one generally finds other features in scanning the slide which arouse suspicion of cancer. Although these associated findings are not uncommon in inflammatory lesions and in various benign neoplasms, their presence makes it necessary to study the slide carefully in order to rule out carcinoma. These findings include the presence of red cells and blood pigment, an increased number of leukocytes, histiocytes, and macrophages, the presence of cells in clusters with crowding of the cells, and the presence of large giant cells or a syncytium of cells.

The Findings in Benign Lesions In addition to its usefulness in the detection of cancer of the genital tract, the vaginal smear is of great help in serving as the indicator of an abnormal function of the ovaries and may show the presence of inflammatory lesions or benign neoplasms in various parts of the genital tract. Thus, for instance, *trichomonads* and the yeast cells and hyphae of *fungi* can be recognized in cytologic smears, although they do not stain as well as with various specific methods for the detection of these organisms. An *atrophic vaginitis* can be readily recognized by the presence of large numbers of basal cells along with a marked increase in leukocytes and histiocytes In *cervical erosions* one notes a large number of basal cells from the ectocervix particularly from its basal layer along with increased numbers of leukocytes and frequently red blood cells and histiocytes. In endocervicitis there is a large amount of cervical mucus heavily infiltrated with leukocytes and excessive numbers of endocervical cells. In *pelvic inflammatory disease*, in addition to numerous leukocytes

there is frequently an increased number of cervical cells, endometrial cells and histiocytes. Many of the cells may assume bizarre forms and peculiar staining reactions which to the uninitiated may arouse suspicion of cancer. In *abortions* the cytologic picture is also often quite unusual and bizarre and has given rise to difficulty because of suspicion of cancer. If the smear is studied carefully, one frequently finds groups of navicular cells similar to those found in normal pregnancy. In addition there are red cells, leukocytes, histiocytes, blood pigment, and sometimes clumps of trophoblastic or placental cells present. Considerable experience is required in the recognition of cells arising from the decidua, the membranes, and various portions of the placenta. Excellent photographs of these may be found in the monograph by Papanicolaou and Traut.

When polyps of the cervix or endometrium are present, there is generally an increased number of cells of endocervical or of endometrial origin, depending on the type of polyp. Such smears may give rise to some difficulty in interpretation since not infrequently many bizarre shapes and clumps of cells are present in addition to red cells and blood pigment. In some instances bizarre forms that resemble basal cells of the prickle variety are observed and probably are due to the occurrence of squamous metaplasia, but on careful study the nuclei fail to show the criteria which have been given as suggestive of cancer.

Irradiation Changes

The cytologic technic has come to play an important role in the follow-up of patients during and after the administration of roentgen or radium therapy, (1) to determine whether an adequate response is being made to this mode of therapy and (2) to detect evidences of recurrence, particularly with regard to further treatment (Graham) Soon after irradiation has been administered there is an increase in the number of necrotic and degenerated cells as well as an influx of histiocytes and macrophages Although the number of neoplastic cells rapidly decreases, bizarre cells, quite different from those present before irradiation was administered, soon appear. Often they are of giant cell size, multinucleated, and show gross nuclear deformities or exhibit peculiar mitotic figures. Their staining reaction is also abnormal, often being deep orange or gold-tinged. Sometimes the nuclei appear shattered and the cytoplasm shows a marked increase in vacuolization. Frequently their staining is rather hazy so that the details of structure are difficult to outline These distorted cells may persist as long as six months or more after treatment, but as a rule they decrease rapidly in number after several months The entire smear then clears and the numbers of leukocytes, mucus, and debris diminish. Recurrence is evidenced by the reappearance of cells with nuclear deformity resembling those originally present. Their recognition, however, so far as staining reaction and vacuolization of the cytoplasm is concerned, may now be more difficult due to irradiation changes which persist.

Results

In reviewing the statistics of the accuracy of the cytologic method for the diagnosis of uterine cancer as reported from various clinics, it is at once evident that the over-all results give a degree of accuracy ranging generally from 95 to 98 per cent. Further analysis of the figures, however, indicates that the percentage

of false positives and false negatives varies considerably in different groups. Papanicolaou and Traut failed to detect neoplastic cells in the vaginal smears of patients with demonstrable carcinoma of the cervix in only 4 of 127 patients and with carcinoma of the fundus in 7 of 53 patients. Thus the incidence of false negative smears for the cervical cases was 3.2 per cent and for the fundal cases 9.3 per cent. In a review of 1,875 cases studied in the Vincent Memorial Laboratory in Boston, Fremont-Smith and Graham found the procedure to have an over-all diagnostic accuracy of over 96 per cent. Further scrutiny of their statistics shows that the percentage error in patients with proved carcinoma is considerably higher than in the negative cases. Thus an incorrect diagnosis was made in 10.3 per cent of 154 carcinoma cases, while false positives were reported in 2.9 per cent of 861 negative cases, although the over-all total diagnostic error was but 4 per cent. Ayre, in a study of 580 cases, reported missed diagnoses amounting to 6 per cent in 100 patients who had a positive tissue diagnosis of cancer. False positive smears, however, occurred in only 9 patients or 1.9 per cent of the 475 who were negative for carcinoma. Jones and her co-workers had an error of 11 per cent in false positives and 9 per cent in false negatives in a group of 432 cases, in 82 of which a final diagnosis of cancer was established.

In reviewing the factors which may influence the results of cytologic examinations the following appeared to be of most significance:

Collection of Smears. It is of course apparent that the prepared smear must contain cells shed from the lesion if the smear is to be of value. For this reason smears should be taken carefully with special precautions to obtain an adequate sample. Papanicolaou and Traut have shown that even with vaginal smears alone good results can be obtained provided an adequate number of smears is made. In our opinion the most important material is that taken from the vagina in that it contains representative cells from all portions of the genital tract. It is apparent that the percentage of good results can be increased by making additional smears from the endocervix or from cervical scrapings.

The Number of Smears Examined. Unquestionably the larger the number of samples taken from a patient the more accurate the result. Unfortunately this has a certain practical limitation since, if the smear is completely negative and the patient presents no suspicious symptoms or lesions, there would be little reason for repeating smears. On the other hand, if a smear is studied which shows questionable cells, repeat smears should always be obtained. Not infrequently such repetition has been rewarded by eventually finding cells suggestive of cancer.

The Type of Patients Studied. The degree of accuracy is largely influenced by the proportion of normal patients in any group studied. In most instances it is easier to rule out carcinoma on the basis of a perfectly normal smear than it is to make a diagnosis of cancer on a smear which shows many bizarre cells arising from various benign lesions.

The Personal Factor. There can be no question but that the personal factor in the interpretation of vaginal smears plays a large part in the degree of accuracy which can be obtained. Some examiners, particularly early in their experience, will tend to classify cells which are at all bizarre as "suspicious" and as a conse- [illegible] ew false nega- [illegible] s.

Evaluation of Results for Routine Gynecologic Purposes. It will be noted from Table II that in smears taken from patients admitted to the Jefferson Hospital with various gynecologic complaints an accuracy of about 95 per cent was obtained with regard to the presence of malignant tumors when evaluated on the basis of the findings at operation (Scheffey, Rakoff, and Hoffman; Scheffey and Rakoff). Although the results were highly accurate so far as ruling out cancer was concerned, positive cases were missed in as high as 30 per cent if vaginal smears alone were used. This was reduced to 17.6 per cent with the combined use of vaginal and cervical smears. It is apparent, however, that for routine gynecologic purposes the cytologic smear alone is not as accurate as histologic diagnosis obtained by biopsy or curettage and for this reason it should never be used to replace histologic diagnosis. On the other hand, when no lesion is visible and the patient does not complain of symptoms which would lead to a diagnostic biopsy or curettage, then the finding of a positive smear assumes considerable significance and cannot be disregarded, particularly since false positives are relatively rare. By following such patients with repeat smears, and then by biopsy, and curettage, carcinoma has been discovered in patients in whom the lesion might otherwise have gone unnoted. On the other hand, we have repeatedly seen unfortunate instances in which patients have been subjected to major surgery on the basis of a positive smear alone in which no confirmation was obtained by histologic methods.

It is generally agreed that the diagnosis of carcinoma of the endometrium by the cytologic method is more difficult than that of cervical carcinoma, and as a result the percentage of error in fundal cancer is somewhat higher (Table II).

TABLE II

Accuracy of Cytology Smears

	Vaginal Smears Alone *	*Combined Vaginal and Cervical Smears* †
Total number of patients	500	500
Patients with uterine cancer	63	74
Correct results	474 or 94.8 per cent	476 or 95.2 per cent
Correct positives (on cancer cases)	44 or 70.0 per cent	61 or 82.4 per cent
Correct negatives (on non-cancer cases)	430 or 98.4 per cent	415 or 97.4 per cent
False positives (on non-cancer cases)	7 or 1.6 per cent	11 or 2.6 per cent
False negatives (on cancer cases)	19 or 30.0 per cent	13 or 17.6 per cent

* Results on 500 consecutive ward patients read as "unknowns" using a single set of vaginal smears, Jefferson Medical College Hospital.

† Results on 500 patients using vaginal and cervical smears (endocervical and/or cervical scrapings), from patients in the gynecologic ward, Jefferson Medical College Hospital.

Carcinoma in Situ

The cytologic method has particular value for the detection of patients with carcinoma in situ. The chief reason for this is the fact that early lesions often shed a sufficient number of abnormal cells to arouse suspicion of cancer. Indeed, it is a curious fact that it is often easier to make a positive diagnosis on a very early lesion than in some cases of advanced carcinoma in which the neoplastic cells are obscured by considerable necrosis, blood debris, and the like. In some instances

of carcinoma in situ multiple biopsies may be necessary before the lesion can be located. In such cases the circular biopsy method suggested by Scheffey is particularly useful.

Cytologic Smears for Screening Purposes

The fact that the vaginal cytologic smear method is capable of detecting malignant neoplasms in the absence of either a visible lesion or clinical manifestation raised the hope that routine screening of all patients presenting themselves for gynecologic examination or for a cancer detection examination would provide an easy method for the early detection of cancer of the genital tract. That such cases can be discovered in this way has now been repeatedly shown. On the other hand, routine use of cytologic smears for screening purposes has proved somewhat disappointing from certain practical aspects. In a group of almost 5,000 patients studied by us in various cancer detection clinics in Philadelphia, over a four-year period in which more than 12,000 smears were examined, only 7 patients with uterine carcinoma were discovered (Table III). The smear gave a correct positive or suspicious diagnosis in 6 of these 7 cases. However, in all but one of the patients with carcinoma a suspicious lesion was visible or symptoms were sufficiently suggestive to warrant biopsy or curettage even before the smear was taken. In only one case was the suspicion of carcinoma confirmed on the basis of the smear alone. These results as well as those of a similar study by Lombard arouse serious question as to whether the cytologic method is a practical one from a financial standpoint as a routine screening procedure.

TABLE III

Cytology Smears for Screening Purposes

Results of cytologic smears as a "screening" test in Philadelphia cancer detection clinics (July 1944-March 1948)

Number of Patients	4,947
Number of Smears	12,329
Number of Patients with Uterine Carcinoma	7
Correct positive smears	6 or 85.7 per cent
Correct negative smears	Approximately 99.5 per cent
False positive smears	2
False "suspicious" smears	18
"Doubtful" smears	13

Summary

(1) The cytologic smear test is a useful adjunct in the detection of uterine carcinoma.

(2) This test is not intended to replace biopsy or curettage, rather it should be used to select patients who should have the advantages of these standard procedures.

(3) The cytologic method is not as accurate as histologic diagnosis for routine purposes.

(4) Smears taken from the vagina and the cervix yield better results than those from either site alone.

(5) The cytologic test is most useful as a screening method in conjunction with adequate gynecologic examination.

(6) A repeatedly positive cytologic test must be regarded as indicating the possibility of cancer until proved otherwise.

(7) A repeatedly negative smear does not rule out the possibility of cancer.

(8) The cytologic smear test is frequently positive in very early carcinoma which may be missed on initial biopsy.

CANCER OF THE LUNG

Collection of Material

Material available for studying carcinoma of the lung is of two types—expectorated sputum and bronchoscopically removed secretions. Of the two we prefer the latter, for we maintain that (1) early in the course of the disease there is no available sputum, (2) the collection of the material can be more precisely regulated, (3) bronchoscopically removed secretions are more concentrated than is expectorated material and the chances of finding neoplastic cells are, therefore, greatly enhanced, and (4) when secretions are not present, the segment of the bronchus containing the tumor can be conveniently washed with saline and material thus obtained for cytologic examination.

When facilities for a bronchoscopic examination are not available, however, examination of *sputum* is definitely worth while. Its collection is relatively simple. If it is to extend over a 24 hour period a preservative of 95 per cent alcohol is necessary This is placed in a wide-mouthed receptacle and the patient is instructed to expectorate directly into the container. If, on the other hand, a morning specimen is desired the patient should be instructed to rinse his mouth clean of excessive debris and to cough from the depths of his lungs. This is to insure the securing of sputum rather than saliva. If the material can be examined within a half hour or so, adding a preservative is not necessary, but if the interval between collection and examination is longer the material should be collected in 95 per cent alcohol

The procedure of securing *bronchial secretions* with the aid of a bronchoscope must be precise. In preliminary studies a roentgenogram of the chest is mandatory in order to localize exactly the suspected tumor site. The bronchoscopic examination is performed in the usual manner If the trachea and larger bronchi contain secretions these are aspirated and discarded. The end of a flexible tipped aspirator (straight for the lower lobes, curved for the right middle and both upper lobes) is then inserted into the bronchus which drains the suspected tumor area, and secretions are aspirated and collected in a special collector. The collector, which is attached to the end of an ordinary aspirator, has a short horizontal hollow tube from which emerges a hollow side arm This fits into an ordinary test tube When suction is applied a vacuum is created in the test tube and the secretions, as they pass the orifice, drop into the lumen of the tube. The collector was designed by Doctor Clerf in order to do away with excess tubing. If secretions are not available the involved bronchial segment may be gingerly washed with saline. To accomplish this the patient is turned on the side containing the lesion and the table is tilted so that the feet are slightly lower than the head if the lesion is in the lower lobes, or the head is slightly lower than the feet if the lesion is in the upper lobes. With the bronchoscope in place, and under di-

rect vision, saline is introduced into the bronchus draining the suspected tumor site until a return is visible. Ordinarily 2 to 5 cc. are all that is necessary. The saline is then allowed to remain in the bronchus for a minute or two, after which the patient is asked to cough and the return, which should be thick and sticky (not watery), is aspirated in the usual manner. If the yield is negligible, the process may be repeated once or twice at the same sitting.

In the *laboratory* the sputum or the bronchoscopically removed secretions are poured into a Petri dish and examined over a black background. With the end of a broken applicator small gray particles (which may represent fragments of tissue), the heavier mucoid areas, or the areas that are streaked with blood are fished out, transferred to clean glass slides, and smears prepared and stained in the manner already indicated.

NON-NEOPLASTIC CELLS

Epithelial cells are invariably present in a properly secured specimen. These are of two types—buccal and bronchial. *Buccal epithelium* is always found in sputum but ordinarily should not be present in bronchoscopically removed secretions. It is easy to identify. The cells are usually large, polyhedral, and possess distinct borders. The cytoplasm is abundant, homogeneous, and stains blue, green, pink, or combinations of these colors. The nucleus is round, small, and either centrally or slightly eccentrically placed. *Bronchial epithelium* is quite variable It may be present in masses, small clumps, or single cells. In *masses* the over-all hue is usually reddish-orange or bluish-green. The margins of the clumps are irregular. The cell borders are ordinarily fairly indistinct; the cells are more or less polyhedral, and the cytoplasm is moderate in amount. The nuclei are round or oval, and uniformly and lightly stained. When the angle is correct, fine focusing in the presence of subdued light usually reveals cilia along the border or over the surface. Sometimes, however, the cells are so turned that the cilia are covered in which case they are invisible. When normal epithelial cells occur in *smaller clumps* they are more transparent and their architecture is more readily discernible. The borders of the masses are usually angulated. The cells are tall, columnar, or cuboidal. The cell boundaries are indistinct; the free edge usually contains cilia; the cytoplasm is abundant and ordinarily stains bluish-green, and the nuclei are round, oval, basilar in position, and uniformly stained. *Single* epithelial cells are essentially similar. In addition, however, both they and the clumps often show varying degrees of *degeneration*. Under such circumstances the cells may become quite irregular and, when cilia have disappeared, some difficulty may be encountered in distinguishing them from neoplastic cells. Degenerating cells are usually considerably larger. The borders are less distinct and frequently evenly broken. The cytoplasm is somewhat granular, occasionally vacuolated, and stains a light, smuggy bluish-green. The nuclei may be three or four times the normal size. The nuclear membrane is quite indistinct and the nucleoplasm usually reveals a ground glass appearance. Vacuoles, sometimes present within the nucleus, may be mistaken for nucleoli. One valuable point in precisely labeling these cells is the fact that most of the non-neoplastic epithelial cells in the same smear show varying degrees of degeneration and some of these will invariably exhibit cilia. Since it may be stated axiomatically that any cell, no

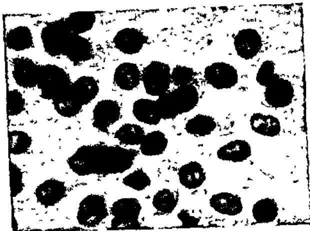
matter how irregular, that contains cilia is not neoplastic the uncertainty should be immediately dispelled. Finally, there are single epithelial cells, presumably derived from the basal layer, that are round or polyhedral and considerably smaller. The borders sometimes are rather frayed; the cytoplasm is sometimes scanty and bluish-green, the nuclei are round, uniform in size, and lightly stained.

Inflammatory cells are usually easy to identify. *Neutrophils* are of the ordinary type. They are round, sharply defined, have a moderate amount of light bluish-green cytoplasm, and reveal typical, evenly stained, lobulated nuclei. *Lymphocytes* are considerably smaller. As usual the cell borders are fairly distinct, the cytoplasm is scanty or imperceptible, the nuclei are round, of equal size, and rather heavily stained. The uniformity of the lymphocytes tends to distinguish them from anaplastic carcinoma *Plasma cells* are larger than lymphocytes. They are round or oval; the cell borders are distinct; the cytoplasm is moderate in amount and bluish-green, and the nuclei are round, eccentric, and rather deeply stained. *Phagocytes* are the largest cells of the inflammatory group. They are usually round or oval, the margins are sharp, and the cytoplasm is abundant, homogeneous, reticulated, or vacuolated, and stains bluish-green to green. Frequently it contains carbon pigment and it is the presence of this carbon pigment that is sometimes of considerable value in ruling out neoplastic cells. The nuclei are of varying sizes but are usually quite large, round, somewhat eccentric in position, and deeply stained. *Giant cells* of the Langhans' or foreign body type are also sometimes encountered. They are similar in all respects to giant cells that are seen in ordinary histologic sections. They usually consist of a large mass of cytoplasm that stains bluish-green or light green and they contain two, three, or more round or oval uniformly appearing, often piled up, lightly stained nuclei. *Erythrocytes* are sometimes abundant. They appear no different than they do in smears of peripheral blood. Aside from the cellular elements there may be present fibrin, carbon pigment, necrotic tissue, and bacteria.

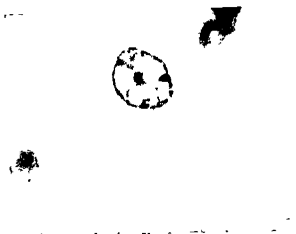
NEOPLASTIC CELLS

Neoplastic cells, as would be expected, are as diversified in smears of secretions from the lungs as they are in histologic sections of the corresponding tumor. For the sake of description they may be conveniently divided into three categories—squamous, anaplastic, and intermediate

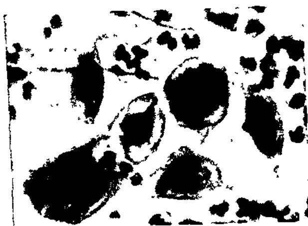
They appear either singly or in clumps *Single cells* vary greatly in shape and size. Ordinarily, however, they are considerably smaller than are the pavement cells that arise from the buccal mucosa. The borders are usually sharp, and the cells are round, polyhedral, or assume an oblong appearance. The cytoplasm is homogeneous and, as already stated, stains pink, yellow, orange, or various combinations of these colors. The nucleus is usually central in position, round, and extremely hyperchromatic. Sometimes groups of these cells form definite epithelial pearls. As such they are arranged in whorls and they become crescentic



A



B



C



D

PLATE I

(A) Normal endometrial cells These are among the smallest cells normally found in smears, and are characterized by dark blue staining nuclei and a small rim of basophilic cytoplasm. They generally contain several prominent chromatin granules in the nucleus.

(B) A typical tadpole cell from a patient with a well differentiated cervical cancer· Notice the large nucleus in proportion to the size of the cell, the chromatin around the edge of the nucleus, and the prominent nucleolus.

(C) Smear from a patient with an adenocarcinoma of the cervical canal: Round and pyriform cells with large, dense, irregular nuclei appearing in groups throughout the specimen.

(D) Smear from a patient with adenocarcinoma of the endometrium: Notice clump of endometrial cells showing marked variation in size, marked enlargement of the nuclei, and irregular distribution of clumping of chromatin.

(A, B, and C from Rakoff, A. E : Normal and Abnormal Cytology of the Female Genital Tract. in *Seminar*, published by Sharp and Dohme, November, 1948, pp. 4-21.)

and flattened. The cytoplasm appears as before and the nuclei are elongated. Squamous epithelial cells appearing in *clumps* have less characteristic and distinctive features for the simple reason that they are as a rule several layers thick. Because of this and because they may be confused with clumps of normal epithelial cells, we usually pay less attention to them than we do to single cells. The clumps are of varying sizes. The periphery is ordinarily irregular and the over-all hue is of a bluish-green to deep orange-red. Usually the cells are larger than normal. The borders are indistinct; the cytoplasm is less abundant, and the nuclei are on an average larger than those found in normal epithelium. As a rule, they disclose considerable variation in size, shape, and staining qualities. Sometimes they are lightly stained and vesicular, whereas at other times they are intensely hyperchromatic. Cilia, in contrast to normal epithelium, are never seen.



FIG 3 —Intermediate variety of carcinoma of the lung, showing single and clumped neoplastic cells. They are of varying shapes, have a moderate amount of cytoplasm, and disclose irregular hyperchromatic nuclei. ×400.

Anaplastic neoplastic cells are of two varieties. More commonly they are two to four times the size of lymphocytes and show considerable variation in shape. They may be round, oblong, or variously deformed. The cytoplasm is usually extremely scanty or imperceptible. The nuclei are sharply defined and, although they are homogeneous, show considerable hyperchromatism. As a rule, the cells occur singly but small clumps are also sometimes encountered. Less commonly the cells are considerably smaller approaching somewhat the size of ordinary lymphocytes. They are round or oblong, reveal practically no cytoplasm, and disclose intensely hyperchromatic nuclei. Two features that tend to distinguish them from lymphocytes are the slight but definite variation in shape of the nuclei and the intense hyperchromatism.

In the category of *intermediate variety* we have grouped all the other types of carcinoma of the lung, for we maintain that a more precise cytologic diagnosis cannot definitely be made. As would be expected, therefore, this constitutes the most heterogeneous group and the variations are almost endless. Again the cells appear singly or in clumps (Fig. 3). The size varies tremendously from cells that are no larger than lymphocytes to monstrous forms that occupy more than a

single high power field of a microscope. The shape passes from round or oval on the one hand to irregularly serrated and polyhedral on the other. The cytoplasm may be so scanty that it is hardly visible, or it may be extremely abundant. It may be homogeneous, finely granular, or even occasionally vacuolated, and its color is blue to gray with varying amounts of green added. The nuclei, too. are extremely bizarre. Some are small and round or oval while others are grotesque. The nucleoplasm may be abundant and intensely hyperchromatic or it may be scanty and watery. One or more nucleoli are sometimes present but usually they are entirely absent. Cells that exist in clumps show similar variations but to a lesser degree since the thickness usually obscures the cellular detail.

RESULTS

Our results as of May 26, 1949, are as follows: In a total of 307 cases of carcinoma of the lung, neoplastic cells were present in bronchial secretions in 272 or 88 6 per cent In the same group of cases a bronchoscopic biopsy was possible in only 104 cases or 33.8 per cent In addition, however, there were stenosis, rigidity, etc, in 87 cases. In the entire group bronchoscopy was completely negative and neoplastic cells were present in 94 cases or 30 6 per cent.

We have not made an overdiagnosis of carcinoma of the lung in the last three years. This we accomplish by rendering a positive diagnosis only when we are certain that the cells are neoplastic. In all other cases in which we are not absolutely sure we so word our report and ask for another examination. This may be repeated any number of times (eight has been the greatest number so far) until we can precisely label the smears as positive or negative.

COMMENT

In recent years the method of diagnosing carcinoma of the lung by cytologic means has become quite popular. Although the technic has varied slightly, the end results are comparable to those recorded above. Thus Woolner and McDonald use both sputum and bronchial secretions and have modified the technic of Papanicolaou to the extent that they use only hematoxylin and eosin as their stains In September 1947 they reported on 70 cases in which the results of the examination were positive, while in May 1949 they enlarged their series to 400 patients in whom a positive diagnosis of carcinoma was rendered. Their false positive error was approximately 2 per cent and their false negative error was approximately 30 per cent In other words, in their hands a correct positive diagnosis of carcinoma of the lung was rendered in 70 per cent of cases of cancer examined In a series of 54 cases of carcinoma of the lung studied by McKay and co-workers a positive cytologic diagnosis was made in 40 or 74 per cent and a false positive diagnosis was made in 3 cases

Richardson and his associates prefer bronchoscopically removed secretions to sputum and histologic sections of paraffin-embedded material to smears After aspiration the material is fixed in 10 per cent formalin, agglutinated by picric acid, embedded in paraffin, sectioned in the routine manner, and stained with hematoxylin–eosin–orange G In a series of examinations from 17 cases of carcinoma collected from various hospitals they found neoplastic cells in bronchoscopically removed secretions in 10 cases or 66.7 per cent. In another series of 19 cases of

carcinoma of the lung in which the studies were made under the direction of one bronchoscopist they found neoplastic cells in 17 cases or 89.4 per cent. This study indicates one point which cannot be overemphasized, namely, the precision that is necessary in order to obtain constantly good results.

Shatz and co-workers, working with sputum coughed from the tracheobronchial tree, fix their smears in equal parts of 95 per cent alcohol and ether and then stain them with hematoxylin and eosin. In 40 proved cases of carcinoma of the bronchus a positive diagnosis was made in 29 or 72 per cent. Farber and his associates recently reported on 100 cases of proved *bronchogenic carcinoma*. Sputum from 89 of these showed "suspicious cells" in 63 or 71 per cent. Bronchoscopically removed secretions in 45 of the cases were reported as positive in 26 or 58 per cent. They stated that when a series of five specimens of sputum was examined the accuracy was increased to 90 per cent. Liebow and associates, from a study of smears of both sputum and bronchial secretions in a series of 51 cases of carcinoma of the lung, concluded that the bronchial smear method appears to be twice as sensitive as the sputum smear method in arriving at a correct diagnosis. Finally, Altgauzen has been studying secretions and fluids from various *portions of the body including sputum over a 25 year period by making thin* smears and examining them under the microscope without staining. In his report he stated that 216 patients with carcinoma of the lung have been diagnosed by this method, but he did not state the total number of cases of carcinoma of the lung encountered during this time.

CANCER OF THE PROSTATE

Collection of Material

Prostatic secretions are obtained by massaging the prostate with the index finger by way of the rectum. In order to keep the material as concentrated as possible care should be taken to avoid emptying the seminal vesicles. For the same reason attempts should be made to strip only that portion of the prostate that contains the suspected tumor. As the drops appear at the external urethral *meatus they are collected on three new clean glass slides*. Each of these is then covered with three additional slides and six smears are thus prepared in the usual manner. Originally, we collected the secretions in a test tube but later we abandoned this procedure because too much of the material was lost on the sides of the test tube. When the secretion is abundant this is not a particularly great problem, but when it is scanty (consisting, for example, of only a drop or two) the end result is quite unsatisfactory.

Non-Neoplastic Cells

Normal epithelium in prostatic secretions is derived from four sources—bladder, urethra, seminal vesicles, and prostate.

Vesical epithelium is encountered when urine is expressed at the time of collecting the secretions, and when there is inflammation of the vesical orifice of the bladder. The cells are of two types—superficial pavement and deeper mucosal. The former are similar to buccal cells and urethral cells *and offer no difficulty in* identification. The latter, however, may be quite confusing. The cells appear both

singly and in large clusters. The clusters consist of sloughed pieces of normal mucosa and Brunn's nests. The periphery of the former is usually rough and irregular, while that of the latter is smooth, circumscribed, and surrounded by a distinct basement membrane. In either case the over-all hue is usually light brown. The cells are always smaller than are the cells in clumps in cases of carcinoma. The cell boundaries ordinarily are quite distinct and the cells, as a rule, are polyhedral and remarkably uniform in size. The cytoplasm is moderate to scanty in amount, and the nuclei are round or slightly oval, centrally placed, relatively large, and evenly and lightly stained. It is the regularity of the cells and their relatively smaller size that aids in distinguishing such clumps from clumps of neoplastic cells. In some cases, however, when carcinoma of the prostate is well differentiated the similarity may be quite striking.

Urethral epithelium is easy to identify. It consists of large polyhedral and irregular flat pavement cells similar to those found in the mouth. The borders are distinct and sometimes curled. The cytoplasm is homogeneous, abundant, and stains all colors of the rainbow, particularly blue, green, pink, and yellow. The nuclei are relatively small, round, uniform in size, and lightly and evenly stained.

Seminal vesical epithelium ordinarily is also easily recognizable. The cells vary considerably in shape and size. At one extreme they are relatively small and more or less cuboidal, while at the other extreme the cells are of giant proportions and irregular. Most commonly they are intermediate in size and round or oval. The cell borders are always distinct and the cytoplasm is abundant, deeply stained, somewhat basophilic, and frequently contains granules of brown pigment (a pathognomonic feature). The nuclei are ordinarily quite large, sharply defined, round, and deeply stained. Often spermatozoa are found both free and agglutinated to the surface of the epithelial cells.

Prostatic epithelium is found as single cells and clumps of cells Single cells are polyhedral or cuboidal The borders are always distinct. The cytoplasm is moderate in amount and bluish-green The nuclei are round or oval, sharply defined, uniform in appearance, and lightly and evenly stained. When the cells are in the process of degeneration they become considerably larger, frequently ballooned, and then disclose ill defined irregular borders. The cytoplasm becomes granular or even vacuolated. The nuclei are somewhat swollen, smudged, and pushed to one side. Prostatic epithelium that appears in clumps or sheets is similar to the nondegenerating normal epithelium. It presents a striking uniformity of cells. The borders are polyhedral and sharply defined. The cytoplasm is moderate in amount and bluish-green and the nuclei are round or oval, uniform, and centrally placed.

Nonepithelial elements offer little or no difficulty in the diagnosis of carcinoma. Cells of inflammatory origin are identical with those already described under carcinoma of the lung. The phagocytes, however, do not contain any carbon pigment. Sometimes they are considerably larger than those found in bronchial secretions and they may contain an abundant amount of ingested material that is presumably lipoid. At any rate, they may be somewhat ballooned and their cytoplasm may be finely or coarsely vacuolated. The noncellular elements consist of debris, lecithin granules, and prostatic concretions The last are round or oval,

sometimes concentrically laminated, hyaline bodies that, with the stain employed, assume a bluish-green appearance.

Neoplastic Cells

Since carcinoma of the prostate is as pleomorphic as carcinoma of the lung the cells encountered in smears of secretions are just as variform. For the sake of uniformity they too may be divided into three categories—well differentiated, anaplastic, and intermediary.

In *well differentiated*, more or less medullary type of growths, the cells in the smears appear in sheets or large clumps (Fig. 4). The periphery of the masses is usually irregularly outlined and the over-all hue is light brown or light blue. The cells are considerably larger than are those found in clumps of normal or hyperplastic epithelium. The borders are always indistinct or entirely erased. The cytoplasm is relatively scanty in amount and usually homogeneous. The nuclei are comparatively large and although usually round or oval, they show a distinct

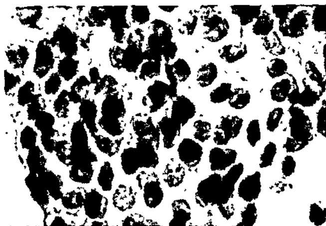


Fig 4.—Well differentiated carcinoma of the prostate, showing a mass of ill defined cells with relatively scanty cytoplasm and large nuclei ×400
(Herbut, P. A *Am J Clin Path*, *19* 315, 1949)

variation in size. The borders are sharp. The nucleoplasm is, as a rule, finely granular, evenly dispersed, and discloses definite hyperchromatism. Nucleoli are rare and mitoses are practically never seen. Almost invariably there are single neoplastic cells in the same smears These are essentially similar to the cells already described. The one outstanding feature which they possess is the indistinct, frayed, irregular margins of the cells

Anaplastic carcinoma in smears is the most difficult of all to recognize. The cells are practically always single or in clumps of not more than three or four (Fig. 5). They are small in size and measure not more than one and a half to twice the diameter of a lymphocyte. The borders, as before, are indistinct. The cytoplasm is extremely scanty, light bluish-green, or is not demonstrable at all. The nuclei are oval or oblong and hyperchromatic.

Cells of the *intermediate type* represent all carcinomas that fall between the two extremes just described. Accordingly, they are quite varied. In some of the *better differentiated adenocarcinomas* they often appear in rounded, giant, cell-

like masses. The cytoplasm consists of a conglomerate mass that sometimes occupies more than a single high power field. The periphery of the mass is sharply circumscribed but does not contain a basement membrane. Internally there are no cell borders demonstrable. The cytoplasm is homogeneous or finely granular and ordinarily light blue. The number of nuclei varies from about six to 24; they may be evenly dispersed throughout the mass, or they may be clumped in one area or another. Frequently they are superimposed on each other. As in the well differentiated carcinomas they are usually large, sharply circumscribed, round or oval, quite regular in appearance, and show a moderate degree of hyperchromatism. In *adenocarcinomas* that *show* considerable *vacuolization* of the cells, the fragments of acini that are extruded in the secretions are often seen as clumps with serrated or scalloped borders. In these the cell boundaries are

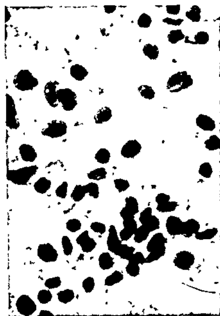


FIG. 5.—Anaplastic carcinoma of the prostate The cells are single and possess a scanty or moderate amount of ill defined cytoplasm and somewhat irregular relatively small nuclei ×400 (Herbut, P A, *Am J Clin Path*, *19* 315, 1949.)

usually fairly distinct and the cells are somewhat ballooned. The cytoplasm is reticulated or finely vacuolated. The nuclei are relatively small but absolutely enlarged. They are round or oval, more or less homogeneous, and hyperchromatic. At other times the cells may appear singly or in small collections and present irregular borders. The cytoplasm may be moderate in amount, drawn out into long sharply angulated processes, and stains light bluish-gray The nuclei may be relatively large and round. The boundaries are sharply delineated. The nucleoplasm is somewhat watery, clumped, and nucleoli may be prominent. In the *more undifferentiated tumors*, particularly those approaching a squamous cell type of carcinoma, the cells become extremely bizarre. They may be many times the size of normal prostatic cells. The borders may be extremely irregular and angulated. The cytoplasm is deep bluish-green The nuclei vary tremendously in

shape and size and are extremely hyperchromatic. Aside from specific cells described in this category there are, as one would expect, numerous variations and endless gradations from one to the other.

RESULTS

In a total of 520 smears of prostatic secretions we encountered 66 cases of carcinoma of the prostate. Of these the diagnosis was proved histologically in 48. In the remaining 18 cases it was clinically certain that the prostate was extremely hard and nodular, metastases were present in the bones, and the serum acid phosphatase was elevated. Neoplastic cells were present in the secretions in 45 or 81.8 per cent of the 66 cases. An equivocal diagnosis was rendered in 16 additional cases Most of these 16 were encountered in the early part of our study and a recent review shows that equivocation was not justified. Also in the early part of our study a frank overdiagnosis was made in 3 cases. To avoid these errors we, at present, render a positive diagnosis only in cases in which we are absolutely certain that the cells are neoplastic. In others, we ask for a repeat examination until we can decide one way or another and, finally, we end up by stating that there are or there are not neoplastic cells present.

COMMENT

In recent years the only noteworthy additional paper on neoplastic cells in prostatic secretions is that by Albers, McDonald, and Thompson. Their technic

of the prostate they obtained secretions in 24. In 19 of these, secretions were positive for neoplastic cells, and in 13 of the 19 the diagnosis was confirmed histologically. Secretions were positive and tissue was negative for carcinoma in one case. In an additional series of 100 cases of benign hypertrophy of the prostate they discovered neoplastic cells in 3 cases, that is, cases in which carcinoma was not suspected clinically

While there is no doubt that neoplastic cells can be found in prostatic secretions and that they can be precisely labeled as such, the study as a whole has proved rather disappointing. When we embarked on this work it was our hope that we could, by the smear technic, uncover some of the 14 per cent to 50 per cent of the occult carcinomas that are reported to occur in hypertrophied prostates. Actually we have not discovered a single case in which carcinoma was not suspected clinically by at least one urologist. This would lead us to think (1) that the method will never be of practical importance in the diagnosis of occult cancer of the prostate, or (2) that the incidence of occult carcinoma is not what it is purported to be So far the test has been only of confirmatory value.

CANCER OF THE URINARY TRACT

COLLECTION OF MATERIAL

In carcinoma of the urinary tract the material examined is urine. The amount necessary to isolate neoplastic cells need not be great and we have found the night specimen that is voided the first thing in the morning quite satisfactory. Under

such circumstances it is not necessary to add a preservative. Each specimen is merely collected in a clean receptacle and sent to the laboratory. There the sediment is allowed to settle to the bottom. The excessive fluid is poured off and the rest is centrifuged. The sediment is then spread by compression on six clean glass slides that have previously been coated with albumin. After this they are stained in the routine manner by the Papanicolaou technic. Collection of urine from the bladder is likewise satisfactory in carcinoma of the ureter, renal pelvis, and kidney, but in order to localize the lesions precisely a specimen obtained directly from the right or left side by means of a ureteral catheter is indicated. The amount of fluid thus obtained is necessarily small, but it may be treated satisfactorily in the same manner.

Non-neoplastic Cells

Normal epithelial cells found in urinary sediment are ordinarily of two types—large superficial pavement cells and deeper mucosal cells. The *superficial pavement cells* are similar to those found in the mouth and in the urethra. They have already been described under carcinoma of the lung and carcinoma of the prostate. The *deeper cells* are usually found singly. They are three to four times the diameter of erythrocytes and are cuboidal or polyhedral. The borders are sharp. The cytoplasm is light green and it may be rather dense, finely granular, or even reticulated. The nuclei are round or oval, sharply defined, relatively small, and evenly stained. In addition to these types of cells one rarely encounters clumps of epithelium that represent the entire thickness of the mucosa or Brunn's nests. These are seen in cases with severe inflammation of the bladder or in those in which the urinary specimen was obtained after prostatic massage. They are similar in all respects to the cells already described in connection with prostatic secretions.

Aside from epithelial elements the urine may contain inflammatory cells, erythrocytes, bacteria, casts, and debris.

Neoplastic Cells

In well differentiated carcinomas of the urinary bladder the neoplastic cells in urinary sediment are similar to those found in well differentiated carcinoma of the prostate. They usually occur in clumps possessing an over-all light brown hue (Fig 6). The periphery of the clumps and masses is usually irregular. The cell



Fig 6.—Carcinoma of the urinary bladder The cells in the clump are ill defined and possess a moderate amount of cytoplasm and *deeply stained nuclei*. ×400.

borders may be moderately distinct or obscure and the cells are usually polyhedral. The cytoplasm is moderate in amount and homogeneous. The nuclei are relatively large, round, or slightly oval and uniformly but deeply stained. In carcinomas which show lesser degrees of differentiation, and especially in those that tend to resemble a squamous cell type, the cells appear accordingly. In general, they show the same degree of variation in shape, size, and staining qualities as do prostate. Fortunately, however, carcinoma differentiated so that the difficulty of identifying anaplastic cells is practically nonexistent. Cells from carcinomas of the ureter and renal pelvis are similar to those from carcinoma of the urinary bladder.

Results

We have no statistics to report on carcinoma of the urinary tract, for we do not employ the test routinely. Our urologists maintain that whether the smears are positive or negative such patients will be subjected to a cystoscopic examination at which time any vesical lesion can be adequately visualized and a biopsy performed. The procedure, therefore, appears to be somewhat superfluous as far as the bladder itself is concerned. This is not so, however, when the upper urinary tract is the site of the lesion, but the number of cases in this category is by comparison small. We have altogether examined 40 specimens of urine. Although there were 8 cases of carcinoma of the bladder in this group in which positive diagnoses were made cytologically, we have not analyzed the rest to obtain our percentage of accurate diagnosis. By ureteral catheterization we have discovered 2 cases of carcinoma of the ureter. We have not, however, encountered any cases of carcinoma of the kidney.

Comment

Most of the work on carcinoma of urinary sediment has been done in New York City and Rochester, Minnesota. Papanicolaou prefers to mix the urine as soon as possible with 95 per cent alcohol in the ratio of one part alcohol to two parts of urine. It is then refrigerated until centrifuged. The supernatant fluid is poured off. The sediment is smeared on slides that are coated with a thin film of albumin and they are fixed after the edges of the smears show beginning dryness. In 1947 he reported on 240 cases in which there were diagnosed by this method 42 cases of carcinoma of the bladder, 7 cases of carcinoma of the kidney, and one case of carcinoma of the renal pelvis. This last case is presumably the one that was reported in detail in 1949 by Foot and Papanicolaou.

Daut and McDonald in 1947 recorded their experiences with the examination of urinary sediment. At that time they advocated the collection of 10 to 20 cc. of urine in equal amounts of 95 per cent ether alcohol, centrifuging for five minutes at 15,000 r.p.m., decanting the supernatant fluid, placing a drop of the sediment on the slide, spreading it with another slide, allowing it to dry for three to five minutes, and staining with polychrome methylene blue or Papanicolaou stain. They examined 40 specimens, 19 of which were positive for neoplastic cells, and

cytologic investi-

gation of the urinary sediment and presented one case of adenocarcinoma of the kidney and one of carcinoma of the renal pelvis that were diagnosed by this method. They did not, however, give a statistical analysis, but they did state that up to that time they had two false positive diagnoses.

CANCER OF THE ESOPHAGUS

We have had no experience in attempting to diagnose carcinoma of the esophagus by cytologic methods. Anderson, McDonald, and Olsen, however, have had considerable success. They collected the material by the following three methods: (1) At the time of esophagoscopic examination the lesion was touched with a cotton swab and the material was smeared on slides, or fluid was aspirated from the esophagus, centrifuged, and the sediment smeared. (2) After dilatation of the esophagus a cotton applicator was rubbed over the spiral of the dilator and the material smeared on slides. (3) A strip of fine meshed gauze was wrapped around the end of a gastric tube and secured by silk thread. The tube was then passed to the point of obstruction or, if no obstruction was present, to a distance of about 16 in. (41 cm) and then withdrawn. The material which became adherent to the gauze was spread on glass slides, fixed, and stained in the usual manner. By these methods they made the diagnosis of carcinoma of the esophagus in 24 cases and of carcinoma of the cardiac end of the stomach in 26. There was one false positive report. In 8 cases the esophagoscopic examination was negative and the smear was positive, while in 3 cases the esophagoscopic biopsy was positive and the smear was negative.

CANCER OF THE STOMACH

Our experience with carcinoma of the stomach has been extremely disappointing We conscientiously tried the method on two separate occasions. The first was in May 1945 after we had had some success in the diagnosis of carcinoma of the lung, and the second attempt was after favorable results began to appear in the literature. All in all we examined secretions from 17 patients with carcinoma of the stomach and an equal number or more from patients without carcinoma. We analyzed both the fasting contents and saline washings and we made our preparations immediately on fresh material and after the material had been collected in 95 per cent alcohol at the bedside and fixed before reaching the laboratory. Of these 17 cases of carcinoma there were only 2 in which neoplastic cells were discovered in gastric contents. In each of these the lesion was so advanced that the diagnosis was made even before resorting to roentgenographic examination Accordingly we have abandoned the procedure entirely. Other workers, however, have met with some success. A few of the observations are therefore described forthwith.

Papanicolaou and Cooper in 1947 advocated emptying a fasting stomach of its contents with a Levin tube, adding an equal volume of 95 per cent alcohol, centrifuging for 20 minutes at medium speed, pouring off the supernatant fluid, coating slides with albumin, smearing the sediment on the slides, allowing the smears to stand until the edges showed beginning drying, fixing in equal parts of

95 per cent alcohol and ether, and staining by the usual method. In 137 cases studied they encountered 27 cases of carcinoma. A positive diagnosis was rendered in 10 and an equivocal diagnosis in 7 cases. In 10 cases neoplastic cells were not encountered.

Campbell and Grimm in January 1948 advocated an Ewald test meal, aspiration of the stomach contents, dilution with two parts of 95 per cent alcohol, centrifuging at 20,000 r.p.m. for ten minutes, and smearing the sediment. They studied a series of 200 cases of various types of lesions of the stomach, biliary tract, and pancreas. Of the 7 cases of carcinoma of the stomach present in their series they made a cytologic diagnosis of cancer in 5. They made no statement, however, as to the accuracy of diagnosis, or the false negative and false positive reports.

In April 1948 Richardson, Queen, and Bishop advocated washing the stomach several times with 30 cc. of normal saline (1) after the administration of an Ewald meal, (2) after the administration of an alcohol histamine meal, or (3) on the fasting empty stomach. To the washings were added an equal volume of 10 per cent formalin and sufficient aqueous picric acid solution to precipitate the protein and solidify the mucus. The material was fixed for four hours; the supernatant fluid was decanted, and the residue was filtered through a porous paper. The precipitate was then treated as a piece of tissue and stained with hematoxylin, orange G, and eosin. They studied a total of 78 patients, 27 of whom had carcinoma. A positive cytologic diagnosis was made in 13 of these cases or 48.1 per cent.

Ulfelder, Graham, and Meigs in September 1948 reported on an extension of their previous studies They increased the number of openings in a No. 14 Levin tube, introduced it into the stomach, asked the patient to drink tap water, and evacuated the stomach as completely as possible. Following this 100 cc. of normal saline was injected and the patient was placed in several positions. The saline was then withdrawn and reinjected several times and finally the stomach was emptied. Both specimens were centrifuged and the sediment smeared, fixed, and stained by the Papanicolaou method. Of the 48 patients studied there were 14 cases of carcinoma of the stomach, 12 of which were diagnosed as positive by the smear technic. A diagnosis of carcinoma was made in one additional patient who clinically had no demonstrable lesion, and the smears were called negative in one patient with malignant lymphoma of the stomach.

Swartz and co-workers in December 1948 advocated a gastric gavage on a fasting stomach, making thick smears of the aspirated contents, and staining by the Papanicolaou method. They examined a total of 175 patients. Thirty-five of these had carcinoma of the stomach. A positive cytologic diagnosis was rendered in 35 per cent, while a false positive report was rendered in 10 per cent.

CANCER OF THE RECTUM

Although we have examined several smears from rectal lesions, we have had no cases of carcinoma. We have not, however, made any strenuous efforts to detect carcinoma by this means. In December 1948 Mackenzie and Hecht reported one positive case in which they made smears of material aspirated from an unpre-

pared rectum by means of a bulb pipette. The patient had carcinoma of the rectosigmoid junction.

CANCER OF THE BREAST

In recent years we have examined secretions from the nipple in only one case. Neoplastic cells were present and the lesion was later diagnosed as duct papilloma. To our knowledge the current literature contains only one paper on this subject—that of Jackson and Severance published in 1946. They gently expressed secretions from both nipples, prepared smears in a manner similar to making blood films, dried them in air and stained them with Wright's stain. In 584 patients examined the secretions showed tumor cells and papilloma or carcinoma was found at operation in 74.5 per cent, while the secretions showed tumor cells and no papilloma or carcinoma was found in 25.5 per cent.

CANCER OF THE CENTRAL NERVOUS SYSTEM

We have examined about 12 specimens of cerebral spinal fluid in cases of suspected metastatic carcinoma to the brain, but in none have we been able to isolate neoplastic cells.

CANCER IN SEROSAL LINED CAVITIES

Collection of Material

Effusions and exudates from serous cavities are obtained by paracentesis. If the quantity obtained is small it may be centrifuged immediately, but if it is large it is desirable to allow the material to stand in the icebox for several hours. By so doing the cellular elements gravitate to the bottom and the unnecessary supernatant fluid can then be decanted. In either case the sediment after centrifuging is smeared and stained in the usual manner. In order to make the cells adhere to the slides more closely, the slides may first be covered with a thin layer of albumin One great difficulty in handling fluids is the spontaneous coagulation which sometimes occurs. This may be minimized by immediately transferring the collected material to the icebox rather than allowing it to stand at room temperature or, if desired, by adding some anticoagulant. Coagulation, however, does not occur as a rule before some of the cellular elements have had an opportunity to gravitate to the bottom In such cases, therefore, some of the material from the bottom of the receptacle may still be adequate for examination.

Non-neoplastic Cells

Inflammatory cells that are found in serous effusions and exudates are no different from similar cells found in bronchial secretions or elsewhere. *Mesothelial cells,* however, may on occasion be mistaken for neoplastic cells. Ordinarily they are found singly or in groups of not more than two or three. Each cell is usually 14 to 20 microns in diameter. The borders are sharp, the cells are round or polyhedral, and the cytoplasm stains a uniform bluish-green. The nuclei are round or oval, sharply delineated, evenly stained, centrally placed, uniform in appearance, and, as a rule, contain nucleoli. Usually a single nucleus is found within one cell, but sometimes two or even three nuclei may be present. Occa-

sionally mesothelial cells are of gigantic proportions and the nuclei are relatively larger than usual. Their resemblance, therefore, to neoplastic cells may be quite striking. Even in such cases, however, there is a certain uniformity of cellular structure that is not encountered in cases of carcinoma. Of the *other elements* found in serous fluids fibrin is the most important and, of course, is easily identifiable.

NEOPLASTIC CELLS

It is virtually impossible to describe the appearance of neoplastic cells in smears of serous fluids in the space allotted here because such cells can be found secondary to all types of carcinoma anywhere in the body. They are, therefore, most variform. In general the same criteria hold here as elsewhere, namely, variations in size, shape, and staining qualities of the cytoplasm and the nuclei (Fig. 7).



FIG. 7.—A group of neoplastic cells encountered in pleural fluid from a patient with carcinoma of the breast The cytoplasm is scanty and ill defined. The nuclei are irregular and hyperchromatic. ×400

RESULTS

Although we have examined 336 different serous fluids to date, we have not yet had the opportunity to compile statistics. In the group, however, we have had many cases of carcinoma and most organs of the body have been represented. Formerly we employed the cell block technic of Mandlebaum, but because the smear method is much simpler and because we feel that the results are comparable we have discarded it in favor of the Papanicolaou method.

COMMENTS

To our knowledge, the only recent paper to appear on the examination of serous fluid by the smear method is that by Saphir. He examined the fluid as soon as it was collected. Centrifugalization was carried out at 1700 r.p.m. Smears were made of the sediment with a platinum loop on slides that were previously coated with egg albumin and were stained by the Papanicolaou method, Giemsa's stain, and hematoxylin and eosin. He examined 175 fluids, 73 coming from the pleural cavity and 102 from the peritoneal cavity. In this group there were 45 cases of carcinoma, 37 of which were diagnosed correctly by the examination of smears. In 6 additional cases in which carcinoma was present a doubtful diagnosis was rendered. There were, therefore, two false negative reports. An overdiagnosis was made in one case.

CONCLUSIONS

From our experiences with the smear technic in the diagnosis of carcinoma we may draw the following conclusions:

(1) Positive results in the hands of a *competent* and *cautious* observer are just as reliable as are positive results rendered from the study of histologic sections.

(2) Negative results do not mean that the patient is free of carcinoma.

(3) The method has its greatest application in carcinoma of the lung, female genital tract, and serous cavities

(4) So far as we are concerned, the procedure has proved only of confirmatory value in carcinoma of the prostate.

(5) In our hands examination of gastric contents for neoplastic cells has not been satisfactory and the technic has, therefore, been discontinued.

REFERENCES

Albers, D D, McDonald, J R, and Thompson, G. J.: Carcinoma Cells in Prostatic Secretions *J A M A*, *139* 299, 1949

Altgauzen, A Y. Diagnosis of Malignant Growths from Fresh Smears *Am Rev. Soviet Med*, *4*.148, 1946

Andersen, H A., McDonald, J. R, and Olsen, A M.. Cytologic Diagnosis of Carcinoma of the Esophagus and Cardia of the Stomach. *Proc Staff Meet*, *Mayo Clin*, *24* 245, 1949.

Ayre, J E Selective Cytology Smear for Diagnosis of Cancer. *Am J. Obst. & Gynec*, *53* 609, 1947

Ayre, J E · Vaginal and Cervical Cytology in Uterine Cancer Diagnosis *Am. J. Obst. & Gynec*, *51* 743, 1946

Ayre, J E, and Dakin, E Cervical Cytology Tests in Cancer Diagnosis. Glycerine Technique for Mailing *Canad M A J*, *54*.489, 1946.

Campbell, J P, et al Experience with Papanicolaou Stains in the Study of Gastric Contents. *Rev Gastroenterol*, *15* 21, 1948

Daut, R V, and McDonald, J R Diagnosis of Malignant Lesions of the Urinary Tract by Means of Microscopic Examination of Centrifuged Urinary Sediment. *Proc. Staff Meet*, *Mayo Clin*, *22* 382, 1947

Farber, S M, Benioff, M A, and McGrath, A K Diagnosis of Bronchogenic Carcinoma by Cytologic Methods *Radiology*, *52*.511, 1949.

Foot, N C, and Papanicolaou, G N. Early Renal Carcinoma in Situ *J A M A*, *139* 356, 1949.

Fremont-Smith, M, and Graham, R. M. The Diagnosis of Uterine Cancer by Vaginal Smear, in *Progress in Gynecology* New York Grune & Stratton, 1946.

Gates, O, and Warren, S. *A Handbook for the Diagnosis of Cancer of the Uterus by the Use of Vaginal Smears* Cambridge, Mass Harvard University Press, 1947.

Graham, R M Effect of Radiation on Vaginal Cells in Cervical Carcinoma, Prognostic Significance. *Surg*, *Gynec & Obst*, *84* 166, 1947.

Herbut, P A Cytologic Diagnosis of Carcinoma of the Prostate. *Am J. Clin. Path*, *19*.315, 1949

Herbut, P. A, and Clerf, L H Bronchogenic Carcinoma, Diagnosis by Cytologic Study of Bronchoscopically Removed Secretions *J A M A*, *130* 1006, 1946

Herbut, P. A, and Clerf, L H Cancer Cells in Bronchial Secretions *M. Clin. North America*, *30*:1384, 1946

Herbut, P A, and Lubin, E N · Cancer Cells in Prostatic Secretions. *J Urol*, *57* 542, 1947

Jackson, D, and Severance, A O: Cytological Study of Nipple Secretions, Aid in Diagnosis of Breast Lesions *Texas State J Med*, *41* 512, 1946

Jones, C. A, Neustaedter, T, and Mackenzie, L L. Value of Vaginal Smears in Diagnosis of Early Malignancy, Preliminary Report *Am. J Obst. & Gynec.*, *49*.159, 1945.

Liebow, A. A., Lindskog, G. E., and Bloomer, W. E.: Cytological Studies of Sputum and Bronchial Secretions in the Diagnosis of Cancer of the Lung. *Cancer, 1*:223, 1948.

Lombard, H. L.: American Cancer Society, Inc., Round Table Conference on the Cytologic Method of Diagnosis in Cancer, Boston, April 12th and 13th, 1948.

Ludden, T. E., and McDonald, J. R.: Diagnosis of Tumors of the Kidney by Cytologic Investigation of Urinary Sediment. *Proc. Staff Meet., Mayo Clin.*, 22:386, 1947.

Mackenzie, L. L., and Hecht, E. L.: A Case of Carcinoma of the Rectum Diagnosed by the Cytologic Method. *Rev. Gastroenterol.*, 15:915, 1948.

Mandlebaum, F. S.: The Diagnosis of Malignant Tumors by Paraffin Sections of Centrifuge Exudates. *J. Lab. & Clin. Med.*, 2:580, 1917.

McKay, D. G., et al.: Diagnosis of Bronchogenic Carcinoma by Smears of Bronchoscopic Aspirations. *Cancer*, 1:208, 1948.

Papanicolaou, G. N.: Cytology of Urine Sediment in Neoplasms of the Urinary Tract. *J. Urol.*, 57:375, 1947.

Papanicolaou, G. N.: A New Procedure for Staining Vaginal Smears. *Science*, 95:438, 1942.

Papanicolaou, G. N.: New Cancer Diagnosis. Proc. Third Race Betterment Conference, p. 28, 1928.

Papanicolaou, G. N., and Cooper, W. A.: Cytology of Gastric Fluid in the Diagnosis of Carcinoma of the Stomach. *J. Nat. Cancer Inst.*, 7:357, 1947.

Papanicolaou, G. N., and Marchetti, A. A.: Use of Endocervical and Endometrial Smears in Diagnosis of Cancer and of Other Conditions of the Uterus. *Am. J. Obst. & Gynec.*, 46:421, 1943.

Papanicolaou, G. N., and Traut, H. F.: *Diagnosis of Uterine Cancer by the Vaginal Smear.* New York: The Commonwealth Fund, 1943.

Papanicolaou, G. N., Traut, H. F., and Marchetti, A. A.: *The Epithelia of Woman's Reproductive Organs, A Correlative Study of Cyclic Changes.* New York: The Commonwealth Fund, 1948.

Rakoff, A. E.: *Vaginal Smears for the Determination of Ovarian Function, in Progress in Gynecology.* New York: Grune & Stratton, 1946.

Rakoff, A. E.: Some Recent Laboratory Procedures of Importance in Obstetrics and Gynecology (Rh Test, Vaginal Smears for Ovarian Function and Uterine Cancer; New Tests for Pregnancy). *M. Clin. North America*, 29:1546, 1945.

Rakoff, A. E., Feo, L. G., and Goldstein, L.: Biologic Characteristics of Normal Vagina. *Am. J. Obst. & Gynec.*, 47:467, 1944.

Richardson, H. L., Queen, F. B., and Bishop, F. H.: Cytohistologic Diagnosis of Material Aspirated from the Stomach. *Am. J. Clin. Path.*, 19:328, 1949.

Richardson, H. L., et al.: A Cytohistologic Study of Bronchial Secretions. *Am. J. Clin. Path.*, 19:323, 1949.

Rubenstein, B. B.: Vaginal Smear–Basal Body Temperature Technic and Its Application to the Study of Functional Sterility in Women. *Endocrinology*, 27:843, 1940.

Saphir, O.: Cytologic Diagnosis of Cancer from Pleural and Peritoneal Fluids. *Am. J. Clin. Path.*, 19:309, 1949.

Scheffey, L. C.: Symposium on Recent Advances in Gynecology and Obstetrics, Diagnosis and Management of Uterine Carcinoma and Sarcoma. *S. Clin. North America*, 25:1262, 1945.

Scheffey, L. C., and Rakoff, E. A.: An Evaluation of the Cytology Test for Uterine Cancer. *M. Clin. North America*, 32:1563, 1948.

Scheffey, L. C., and Rakoff, E. A.: The Cytology Test for Uterine Cancer. *Phila. Med.*, 43:435, 437, 449, 1947.

Scheffey, L. C., Rakoff, A. E., and Hoffman, J.: Evaluation of the Vaginal Smear Method for the Diagnosis of Uterine Cancer. *Am. J. Obst. & Gynec.*, 55:453, 1948.

Shatz, B. A., Bergmann, M., and Gray, S. H.: Sputum Cell Study for Pulmonary Carcinoma as a Routine Laboratory Test. *J. Lab. & Clin. Med.*, *33:1588, 1948.*

Swarts, J. M., et al.: The Cytologic Diagnosis of Cancer of the Stomach, Preliminary Report. *J. Lab. & Clin. Med.*, 33:1633, 1948.

Ulfelder, H., Graham, R. M., and Meigs, J. V.: Further Studies on the Cytologic Method in the Problem of Gastric Cancer. *Ann. Surg.*, 128:422, 1948.

Woolner, L B, and McDonald, J. R.. Bronchogenic Carcinoma; Diagnosis by Microscopic Examination of Sputum and Bronchial Secretions, Preliminary Report. *Proc. Staff Meet, Mayo Clin*, 22.369, 1947.

Zemansky, A P, Jr.: Examination of Fluids for Tumor Cells, Analysis of 113 Cases Checked against Subsequent Examination of Tissue *Am. J M. Sc*, *175*.489, 1928.

Diaphragmatic Hernia

STUART W. HARRINGTON, M.D.

DIAPHRAGMATIC HERNIA is a general term and is often used to designate any condition in which there is protrusion of abdominal viscera into the thoracic cavity or of thoracic viscera into the abdominal cavity (rare) through an abnormal or defective opening in the structure of the diaphragm. These abnormal or defective openings may be attributed to congenital structural deficiencies of the diaphragm or they may be caused by traumatic laceration or penetration or by inflammatory necrosis of the normal diaphragm. Many of these hernias have a sac as one of their component parts and may be termed "true hernias," but many do not have a sac and may be called "false hernias" or probably more properly "eviscerations" The occurrence of herniation of abdominal viscera through the diaphragm is not uncommon but is relatively infrequent when it is compared with the frequency of occurrence of herniation through the abdominal wall, as more kinds of hernia occur through the diaphragm than through the other walls which encase the abdominal contents. One of the chief causal factors of different types of diaphragmatic hernia is the unusual embryologic formation of the diaphragm, which makes it more susceptible to weak areas through which herniation may occur.

EMBRYOLOGIC ASPECTS

The formation of the diaphragm from embryonic structures is a highly complex process, because its muscular elements are derived from different sources. There is difference of opinion among embryologists as to the amount of diaphragm derived from each embryonic source.

The anterior, lateral, and central parts, which comprise the greater portion of the diaphragm in the adult person, are formed from the transverse septum and fused ventral mesentery. The remaining posterolateral portion is formed by the fusion of the dorsal mesentery and the mesoderm derived from the receding wolffian body, and the pleuroperitoneal membrane derived from the pulmonary ridge. It is difficult to determine the exact amount of the muscle tissue which is derived from each of these structures, since considerable variation probably occurs during the process, but it is likely that the dorsal mesentery forms the posterior and central portions which contain the esophageal opening. The mesodermal cells from the receding wolffian body form the right and left crura. The pleuroperitoneal membrane grows ventrally, closes the remaining opening between the peritoneal celom and the pleural celom by fusion with the transverse septum, and forms the lateral portion of the diaphragm.

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the pleuroperitoneal fissure (foramen of Bochdalek); also through the outer crus and through the esophageal opening Herniation through the dome is common, but cannot be explained on the foregoing basis because the dome, embryologically, is not a fusion region Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuroperitoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

Congenital or Embryologic Aspects of Nontraumatic Hernia and Diaphragmatic Defects

Diaphragmatic congenital defects and nontraumatic hernia occur much more frequently on the left side than on the right. The cause undoubtedly is to be found in the embryonic formation of the diaphragm. This point is a subject of controversy among embryologists I have attempted to show the different states in the formation of the diaphragm in embryos of various sizes but, to arrive at any satisfactory conclusions as to why hernia is more likely to occur in these regions, it is necessary not only to follow the concomitant changes that occur in the developing embryo but also to consider the physiologic manifestations which are present in the constantly changing organism at the same time.

The septum transversum, from which the anterolateral portion of the diaphragm of the adult person is formed, arises from the mesoderm in the upper part of the cervical region Its descent is gradual in the early embryonic weeks, and at the 5 to 6 mm. stage it is opposite the fourth and fifth cervical segments, where it receives its innervation from the branches of the third, fourth, and fifth cervical nerve roots to these segments (the phrenic nerve). At approximately the same period as that in which the septum transversum appears (2 to 3 mm.), the tracheal bud appears from the ventral surface of the esophagus and the liver buds have grown vertically into the undersurface of this descending septum. The anlage of the stomach also has appeared as a definite thickening of the foregut opposite the fourth cervical segment.

Three important developmental processes occur in embryos of the 5 mm. stage First, the pulmonary ridge appears as a definite shelf of mesodermal tissue which forms the pleuropericardial and pleuroperitoneal membranes. The pleuropericardial membrane closes off the pericardial cavity from the pleural cavity at about the 10 to 11 mm. stage and does not enter into the formation of the diaphragm The pleuroperitoneal membrane ultimately will help to fill in the posterolateral portion of the diaphragm. At this stage (5 mm.) the pleuroperitoneal membrane is only a narrow shelf of mesodermal tissue that projects into the celom, marking the caudal dividing line of the pleural and peritoneal cavities, which at this stage are in free communication with each other.

The second noteworthy change is the asymmetric development of the right and left pulmonary buds, which are at a slightly lower level than that of the septum transversum. The right bud grows caudally and posteriorly and an infracardiac bronchus soon develops. The left bud grows almost transversely to the vertical plane and, because of the presence of enlargement of the left side of the heart, an infracardiac bronchus does not develop. This process places the left lung at a somewhat higher level than the right lung.

The third change occurring at this period is the increased activity in the development of the midgut, which, previous to this period, has been practically a straight tube. It begins to elongate, with angulation toward the umbilicus from a cephalic and caudal limb of this portion of the intestinal tract.

On the basis of the foregoing it is seen that at this early period in the development of the embryo, the cavity of the body is beginning to divide into two main cavities, the peritoneal cavity and the pleural cavity, by an incomplete shelf of fetal muscular tissue derived from several sources. Ventrolaterally, this shelf is called the "transverse septum"; dorsally, the less well developed mesodermal shelf is called the "pleuroperitoneal membrane." The intestinal tract with its dorsal mesentery and the wolffian body extend into the celom in a dorsomesial position. At this stage, there is free communication between the two cavities, this opening may be termed the "pleuroperitoneal hiatus." In the 7 mm. embryo, the transverse septum with the pleuroperitoneal membrane begins to migrate caudally, rapidly passing the pulmonary buds and the anlage of the stomach, placing the greater portion of the lung in the pleural cavity and the anlage of the stomach partially above the diaphragm.

In the 9.4 mm. embryo, the liver has become firmly anchored to the right dorsal wall of the body of the plica vena cava. The midgut begins to grow more rapidly and the yolk sac disappears. This action frees the intestine from the umbilicus and rotation of this segment of bowel begins

In the 11 mm embryo, the stomach, which has been practically stationary, now follows rapidly behind the descending septum transversum, and in the 17 mm. embryo it has virtually reached its permanent position This descent is made possible by the sudden elongation of the esophagus. During this descent the right and left dorsopleural recesses are converted into bursae which surround the cardia. The left bursa usually disappears and the right bursa, when well developed, is known as the "infracardiac bursa" and bears a definite relationship to esophageal hernia. At about this period (11 mm.) a physiologic alteration in the abdominal region takes place The celom has not increased enough in size to accommodate the rapid changes which are taking place within its walls and which are augmented by the descent of the septum. As Mall stated: "Since the liver grows downward and crowds upon the rapidly elongating intestine, the intestine must escape it if it has a chance and the coelomic space within the umbilical cord naturally receives it." This phenomenon, known as "physiologic umbilical herniation," provides a reservoir for the abdominal contents until the peritoneal cavity has grown sufficiently to store its own contents The herniated intestine is restored to the abdominal cavity by the growth of the abdominal wall past the fixed mesentery of the intestines. This physiologic herniation begins

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the pleuroperitoneal fissure (foramen of Bochdalek); also through the outer crus and through the esophageal opening. Herniation through the dome is common, but cannot be explained on the foregoing basis because the dome, embryologically, is not a fusion region. Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuroperitoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

Congenital or Embryologic Aspects of Nontraumatic Hernia and Diaphragmatic Defects

Diaphragmatic congenital defects and nontraumatic hernia occur much more frequently on the left side than on the right. The cause undoubtedly is to be found in the embryonic formation of the diaphragm. This point is a subject of controversy among embryologists. I have attempted to show the different states in the formation of the diaphragm in embryos of various sizes but, to arrive at *any satisfactory conclusions as to why hernia is more likely to occur in these* regions, it is necessary not only to follow the concomitant changes that occur in the developing embryo but also to consider the physiologic manifestations which are present in the constantly changing organism at the same time.

The septum transversum, from which the anterolateral portion of the diaphragm of the adult person is formed, arises from the mesoderm in the upper part of the *cervical region. Its descent is gradual in the early embryonic* weeks, and at the 5 to 6 mm. stage it is opposite the fourth and fifth cervical segments, where it receives its innervation from the branches of the third, fourth, and fifth cervical nerve roots to these segments (the phrenic nerve). At approximately the same period as that in which the septum transversum appears (2 to 3 mm.), the tracheal bud appears from the ventral surface of the esophagus and the liver buds have grown vertically into the *undersurface of this descending septum.* The anlage of the stomach also has appeared as a definite thickening of the foregut opposite the fourth cervical segment.

Three important developmental processes occur in embryos of the 5 mm. stage. First, the pulmonary ridge appears as a definite shelf of mesodermal tissue which forms the pleuropericardial and pleuroperitoneal membranes. The pleuropericardial membrane closes off the pericardial cavity from the pleural cavity at about the 10 to 11 mm. stage and does not enter into the formation of the diaphragm. The pleuroperitoneal membrane ultimately will help to fill in the posterolateral portion of the diaphragm At this stage (5 mm.) the pleuroperitoneal membrane is only a narrow shelf of mesodermal tissue that projects into the celom, marking the caudal dividing line of the pleural and peritoneal cavities, which at this stage are in free communication with each other.

The second noteworthy change is the asymmetric development of the right and left pulmonary buds, which are at a slightly lower level than that of the septum transversum. The right bud grows caudally and posteriorly and an infracardiac bronchus soon develops. The left bud grows almost transversely to the vertical plane and, because of the presence of enlargement of the left side of the heart, an infracardiac bronchus does not develop. This process places the left lung at a somewhat higher level than the right lung.

The third change occurring at this period is the increased activity in the development of the midgut, which, previous to this period, has been practically a straight tube. It begins to elongate, with angulation toward the umbilicus from a cephalic and caudal limb of this portion of the intestinal tract.

On the basis of the foregoing it is seen that at this early period in the development of the embryo, the cavity of the body is beginning to divide into two main cavities, the peritoneal cavity and the pleural cavity, by an incomplete shelf of fetal muscular tissue derived from several sources. Ventrolaterally, this shelf is called the "transverse septum"; dorsally, the less well developed mesodermal shelf is called the "pleuroperitoneal membrane." The intestinal tract with its dorsal mesentery and the wolffian body extend into the celom in a dorsomesial position. At this stage, there is free communication between the two cavities; this opening may be termed the "pleuroperitoneal hiatus." In the 7 mm. embryo, the transverse septum with the pleuroperitoneal membrane begins to migrate caudally, rapidly passing the pulmonary buds and the anlage of the stomach, placing the greater portion of the lung in the pleural cavity and the anlage of the stomach partially above the diaphragm.

In the 9.4 mm. embryo, the liver has become firmly anchored to the right dorsal wall of the body of the plica vena cava. The midgut begins to grow more rapidly and the yolk sac disappears. This action frees the intestine from the umbilicus and rotation of this segment of bowel begins.

In the 11 mm. embryo, the stomach, which has been practically stationary, now follows rapidly behind the descending septum transversum, and in the 17 mm. embryo it has virtually reached its permanent position. This descent is made possible by the sudden elongation of the esophagus. During this descent the right and left dorsopleural recesses are converted into bursae which surround the cardia The left bursa usually disappears and the right bursa, when well developed, is known as the "infracardiac bursa" and bears a definite relationship to esophageal hernia. At about this period (11 mm.) a physiologic alteration in the abdominal region takes place. The celom has not increased enough in size to accommodate the rapid changes which are taking place within its walls and which are augmented by the descent of the septum. As Mall stated: "Since the liver grows downward and crowds upon the rapidly elongating intestine, the intestine must escape it if it has a chance and the coelomic space within the umbilical cord naturally receives it." This phenomenon, known as "physiologic umbilical herniation," provides a reservoir for the abdominal contents until the peritoneal cavity has grown sufficiently to store its own contents The herniated intestine is restored to the abdominal cavity by the growth of the abdominal wall past the fixed mesentery of the intestines. This physiologic herniation begins

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the pleuroperitoneal fissure (foramen of Bochdalek); also through the outer crus and through the esophageal opening. Herniation through the dome is common, but cannot be explained on the foregoing basis because the dome, embryologically, is not a fusion region Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuroperitoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

Congenital or Embryologic Aspects of Nontraumatic Hernia and Diaphragmatic Defects

Diaphragmatic congenital defects and nontraumatic hernia occur much more frequently on the left side than on the right. The cause undoubtedly is to be found in the embryonic formation of the diaphragm. This point is a subject of controversy among embryologists. I have attempted to show the different states in the formation of the diaphragm in embryos of various sizes but, to arrive at any satisfactory conclusions as to why hernia is more likely to occur in these regions, it is necessary not only to follow the concomitant changes that occur in the developing embryo but also to consider the physiologic manifestations which are present in the constantly changing organism at the same time.

The septum transversum, from which the anterolateral portion of the diaphragm of the adult person is formed, arises from the mesoderm in the upper part of the cervical region Its descent is gradual in the early embryonic weeks, and at the 5 to 6 mm. stage it is opposite the fourth and fifth cervical segments, where it receives its innervation from the branches of the third, fourth, and fifth cervical nerve roots to these segments (the phrenic nerve). At approximately the same period as that in which the septum transversum appears (2 to 3 mm.), the tracheal bud appears from the ventral surface of the esophagus and the liver buds have grown vertically into the undersurface of this descending septum. The anlage of the stomach also has appeared as a definite thickening of the foregut opposite the fourth cervical segment.

Three important developmental processes occur in embryos of the 5 mm. stage. First, the pulmonary ridge appears as a definite shelf of mesodermal tissue which forms the pleuropericardial and pleuroperitoneal membranes. The pleuropericardial membrane closes off the pericardial cavity from the pleural cavity at about the 10 to 11 mm. stage and does not enter into the formation of the diaphragm. The pleuroperitoneal membrane ultimately will help to fill in the posterolateral portion of the diaphragm. At this stage (5 mm.) the pleuroperitoneal membrane is only a narrow shelf of mesodermal tissue that projects into the celom, marking the caudal dividing line of the pleural and peritoneal cavities, which at this stage are in free communication with each other.

The second noteworthy change is the asymmetric development of the right and left pulmonary buds, which are at a slightly lower level than that of the septum transversum. The right bud grows caudally and posteriorly and an infracardiac bronchus soon develops. The left bud grows almost transversely to the vertical plane and, because of the presence of enlargement of the left side of the heart, an infracardiac bronchus does not develop. This process places the left lung at a somewhat higher level than the right lung.

The third change occurring at this period is the increased activity in the development of the midgut, which, previous to this period, has been practically a straight tube. It begins to elongate, with angulation toward the umbilicus from a cephalic and caudal limb of this portion of the intestinal tract.

On the basis of the foregoing it is seen that at this early period in the development of the embryo, the cavity of the body is beginning to divide into two main cavities, the peritoneal cavity and the pleural cavity, by an incomplete shelf of fetal muscular tissue derived from several sources. Ventrolaterally, this shelf is called the "transverse septum"; dorsally, the less well developed mesodermal shelf is called the "pleuroperitoneal membrane." The intestinal tract with its dorsal mesentery and the wolffian body extend into the celom in a dorsomesial position. At this stage, there is free communication between the two cavities, this opening may be termed the "pleuroperitoneal hiatus." In the 7 mm. embryo, the transverse septum with the pleuroperitoneal membrane begins to migrate caudally, rapidly passing the pulmonary buds and the anlage of the stomach, placing the greater portion of the lung in the pleural cavity and the anlage of the stomach partially above the diaphragm.

In the 9.4 mm. embryo, the liver has become firmly anchored to the right dorsal wall of the body of the plica vena cava. The midgut begins to grow more rapidly and the yolk sac disappears. This action frees the intestine from the umbilicus and rotation of this segment of bowel begins.

In the 11 mm embryo, the stomach, which has been practically stationary, now follows rapidly behind the descending septum transversum, and in the 17 mm. embryo it has virtually reached its permanent position. This descent is made possible by the sudden elongation of the esophagus. During this descent the right and left dorsopleural recesses are converted into bursae which surround the cardia. The left bursa usually disappears and the right bursa, when well developed, is known as the "infracardiac bursa" and bears a definite relationship to esophageal hernia. At about this period (11 mm.) a physiologic alteration in the abdominal region takes place. The celom has not increased enough in size to accommodate the rapid changes which are taking place within its walls and which are augmented by the descent of the septum. As Mall stated: "Since the liver grows downward and crowds upon the rapidly elongating intestine, the intestine must escape it if it has a chance and the coelomic space within the umbilical cord naturally receives it." This phenomenon, known as "physiologic umbilical herniation," provides a reservoir for the abdominal contents until the peritoneal cavity has grown sufficiently to store its own contents. The herniated intestine is restored to the abdominal cavity by the growth of the abdominal wall past the fixed mesentery of the intestines. This physiologic herniation begins

Failure of fusion or failure of proper deposition of the mesoderm at any one of these adjacent points of union may result in congenital continuity of the pleural and peritoneal cavities or a congenitally weak portion in the diaphragm at any of these points. Consequently, from an embryologic standpoint, weak portions might be expected to appear at the points of fusion of these different structures. These portions are situated dorsolaterally at the pleuroperitoneal fissure (foramen of Bochdalek), also through the outer crus and through the esophageal opening. Herniation through the dome is common, but cannot be explained on the foregoing basis because the dome, embryologically, is not a fusion region. Such a hernia may be the result of excessive degeneration of the muscle in the formation of the central tendon or of some pathologic condition. Unilateral absence of the diaphragm probably is the result of the failure of development of the pleuroperitoneal membrane, which usually is found as a narrow ridge of tissue along the posterior wall of the thorax.

Congenital or Embryologic Aspects of Nontraumatic Hernia and Diaphragmatic Defects

Diaphragmatic congenital defects and nontraumatic hernia occur much more frequently on the left side than on the right. The cause undoubtedly is to be found in the embryonic formation of the diaphragm. This point is a subject of controversy among embryologists. I have attempted to show the different states in the formation of the diaphragm in embryos of various sizes but, to arrive at any satisfactory conclusions as to why hernia is more likely to occur in these regions, it is necessary not only to follow the concomitant changes that occur in the developing embryo but also to consider the physiologic manifestations which are present in the constantly changing organism at the same time.

The septum transversum, from which the anterolateral portion of the diaphragm of the adult person is formed, arises from the mesoderm in the upper part of the cervical region. Its descent is gradual in the early embryonic weeks, and at the 5 to 6 mm. stage it is opposite the fourth and fifth cervical segments, where it receives its innervation from the branches of the third, fourth, and fifth cervical nerve roots to these segments (the phrenic nerve). At approximately the same period as that in which the septum transversum appears (2 to 3 mm.), the tracheal bud appears from the ventral surface of the esophagus and the liver buds have grown vertically into the undersurface of this descending septum The anlage of the stomach also has appeared as a definite thickening of the foregut opposite the fourth cervical segment.

Three important developmental processes occur in embryos of the 5 mm stage. First, the pulmonary ridge appears as a definite shelf of mesodermal tissue which forms the pleuropericardial and pleuroperitoneal membranes. The pleuropericardial membrane closes off the pericardial cavity from the pleural cavity at about the 10 to 11 mm. stage and does not enter into the formation of the diaphragm. The pleuroperitoneal membrane ultimately will help to fill in the posterolateral portion of the diaphragm. At this stage (5 mm) the pleuroperitoneal membrane is only a narrow shelf of mesodermal tissue that projects into the celom, marking the caudal dividing line of the pleural and peritoneal cavities, which at this stage are in free communication with each other.

covers the greatest area. There are often areas devoid of muscular tissue situated between the individual bands that arise from the wall of the thorax.

The lumbar portion of the diaphragm arises from the bodies of the lumbar vertebrae and consists of three crura on each side: the inner, middle, and outer crura. The inner crus is much the strongest of the group and arises from the *anterior surface* of the third and fourth lumbar vertebrae. The greater portion of the inner crus is muscular but the inner margins soon become tendinous and unite at the level of the 12th thoracic vertebra. This arch, with the bodies of the 12th thoracic and first lumbar vertebrae, forms a canal for the passage of the aorta and thoracic duct. This is called the "aortic opening"; it is in reality not an opening through the diaphragm but is situated entirely behind the diaphragm. The esophageal hiatus is anterior to, and a little to the left of, the aortic opening. It is entirely surrounded by muscular tissue and is formed by the decussation of the crura on a level with the 10th thoracic vertebra. It transmits the esophagus and its vessels and the two vagi nerves. The middle crus arises from the lateral surfaces of the body of the second lumbar vertebra; it is separated posteriorly from the inner crus by narrow slits which transmit the greater and lesser splanchnic nerves of each side, and the left crus transmits the vena azygos minor. The vena azygos major traverses either the aortic opening or the right crus. The outer crus arises from the internal and external *lumbocostal arches (arches of Haller)*, which arch over the psoas and quadratus lumborum muscles posteriorly.

The lateral lumbar portion of the diaphragm arises chiefly from the inner lumbocostal arch, with only a few fibers arising from the external lumbocostal arch. There is usually a triangular-shaped space of muscular deficiency between the outer crus of the lumbar portion of the diaphragm, the last muscular part of the costal portion of the diaphragm and the 12th rib. The apex of the triangle is curved upward and forward toward the tendinous portion of the diaphragm. The base is turned downward and somewhat backward and rests partly on the 12th rib, but sometimes it extends in front of the body of the psoas muscle. The borders of this hiatus are muscular and are of more or less sphincter-like construction. The space is closed by a membrane, which consists of two sheaths: the upper sheath comes from the pleura and the lower sheath is thin and is a continuation of the iliac fascia. This space was first described by Bochdalek, in 1848, and has been named *the foramen of Bochdalek.*

The central tendon of the diaphragm is reniform, with the central portion slightly curved and extending into the dome, of which the greater portion is on the right side. At the base of this right portion and entirely within the tendon is a large quadrilateral foramen which gives passage to the inferior vena cava. This opening is on a level with the disk between the eighth and ninth thoracic vertebrae.

The diaphragm receives its motor innervation from the phrenic nerve, which originates from the fourth and sometimes through branches from the third and fifth cervical nerves This cervical origin of the innervation of the diaphragm is due to the embryonic derivation of the diaphragm from cervical myotomes which are innervated by the third, fourth, and fifth cervical nerves. These nerves originally may have contained both motor and *sensory fibers* but most anatomists agree that the phrenic nerve is the chief, if not the only, motor nerve to the diaphragm. The presence of some afferent sensory nerve fibers in the phrenic

in the 11 mm. embryo, is well developed in the 22 mm. embryo, and starts on its way toward voluntary reduction in about the 35 mm. embryo.

During this period of greater activity in the abdominal celom, the diaphragm is incompletely formed and the pleuroperitoneal hiatus is patent. The closure takes place on the right side first in about the 17 or 18 mm. embryo and on the left side in about the 19 or 20 mm. embryo. The left side of the liver has largely disappeared and the whole organ has rotated to the right and fused with the right wall of the body, protecting to a great extent the right half of the diaphragm and probably aiding its more rapid completion. The stomach has reached its permanent site below the diaphragm before the left half of the diaphragm is closed. Therefore, the pleuroperitoneal hiatus, patent on the left side, is in direct contact with the rapidly forming and constantly changing hollow viscera during this period of physiologic umbilical herniation.

It would seem that this time of the incomplete closure of the diaphragm in relationship to multiple rapid changes which are taking place in the embryo is of great importance in the preponderance of left-sided congenital defects. To recapitulate, these changes consist of: (1) occurrence at this time of the normal physiologic umbilical herniation, (2) patency of the hiatuses connecting the peritoneal and pleural cavities, (3) sudden descent of the diaphragm, a descent which is considerably in advance of the descent of the stomach, (4) shift of the liver to the right because of anchorage and degeneration of the left lobe from vascular change and pressure, (5) presence of hollow mobile viscera on the left side, (6) elevated position and smaller size of the left lung, (7) rotation of the stomach to the left, and (8) presence of bursae at the esophageal opening.

On the basis of the foregoing material it is seen that embryonic herniation would occur most commonly in the 11 to 20 mm. embryo. Congenital herniation of somewhat later formation can be explained on many of the same grounds. It is the result of failure of parts of the diaphragm to mature, or of excessive degeneration of muscular elements in the formation of the central tendon.

ANATOMIC ASPECTS

The diaphragm is a single, independent, dome-shaped muscle arising from the circumference of the lower part of the thorax. The diaphragm when it is normally formed, completely separates the abdominal and thoracic cavities. The muscular structure of the diaphragm in the adult person is divided into three portions, namely, the sternal, costal, and lumbar portions according to the origin of each. The sternal portion is the weakest and the lumbar is the strongest. All three portions are inserted into the margin of a central tendon. The sternal portion consists of a few slender fasciculi arising from the posterior surface of the xiphoid process. There are muscular deficiencies on each side of the process filled with areolar tissue and covered with pleura and peritoneum through which the superior deep epigastric vessels pass These deficiencies are called the "foramina of Morgagni" or "Larrey's spaces." The costal portion of the diaphragm forms the main part of the dome of the diaphragm and arises by broad bands of muscle from the lower six costal cartilages and from the 11th and 12th ribs, interdigitating with the transversalis muscles. This portion of the diaphragm



FIG. 2.—Para-esophageal type of esophageal hiatus diaphragmatic hernia in a woman 38 years of age. (*a*) and (*b*) Herniation of a third of the stomach into the *left* thoracic cavity can be noted, with the stomach incarcerated in a hernial sac. The patient also had a duodenal ulcer. (*c*) On dismissal three weeks after abdominal repair of the hernia, the entire stomach is below the diaphragm. The patient was placed on medical treatment for duodenal ulcer.

nerve will explain the presence of referred pain in the neck, which is often associated with disorders of the diaphragm. Some anatomists are of the opinion that the peripheral part of the diaphragm receives some degree of motor innervation from the lower intercostal nerves

The circular muscle bundles of the esophageal hiatus are innervated chiefly by the phrenic nerve of the same side, regardless of whether the muscles originate from the crus of the same side or from that of the opposite side. There also may be some degree of cross innervation from the phrenic nerve on the opposite side.

In considering the normal relationship between the esophageal hiatus and the lower end of the esophagus and cardia, I wish to mention again the fact that the esophageal hiatus is normally situated to the left of the medial line, at the level of the upper border of the tenth thoracic vertebra, in the dorsal part of the dome of the diaphragm

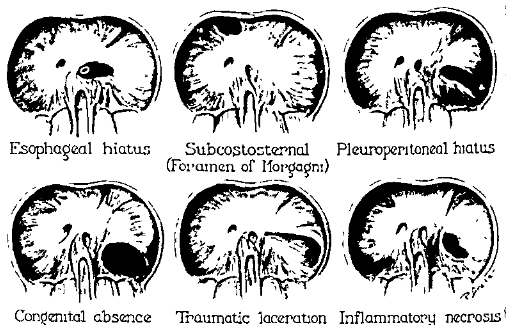


FIG 1 —Congenital structural defects and traumatic lacerations of the diaphragm which cause the commoner types of diaphragmatic hernia.

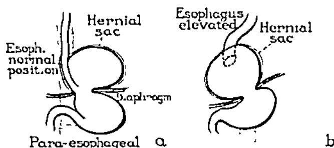
The muscular elements that form the muscular ring of the hiatus usually originate from the median portion of the right crus but the hiatus may be formed by the crossing of both right and left crura after they have united in front of the aorta to form the aortic orifice (Fig 1) This ring of muscle of the hiatus loosely approximates the lower end of the esophagus but is not directly attached to it.

Diaphragmatico-esophageal Membrane

Fixation of the diaphragm to the lower end of the esophagus and to the cardia of the stomach is obtained by the diaphragmatico-esophageal membrane. This membrane consists of elastic and fibrous tissue originating in the fascial coverings of the diaphragm, mostly those of the abdominal side but partly those of the

thoracic side of the diaphragm (Figs. 2, 3, and 4). This elastic and fibrous membrane has its origin lateral to the muscular ring of the hiatus, over which it passes, with slight attachments, to fill the space between the inner margin of the muscle and the esophagus; it is inserted into the lower 2 or 3 cm. of the esophagus and into the upper 1.5 to 2 cm. of the stomach, in a fanlike manner. This elastic and fibrous membrane constitutes a flexible connection between the diaphragm, esophagus, and cardia, and permits of a certain amount of mobility during the act

ESOPHAGEAL HIATUS HERNIAS



PULSION TYPE HIATUS HERNIAS
(Incompetent hiatus)

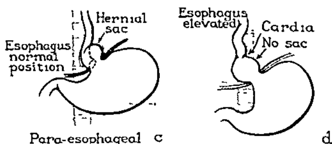


FIG 4.—Different types of esophageal hiatus hernias (*a*) Esophageal hiatus hernia with herniation of the cardiac end of the stomach through the esophageal hiatus, the esophagus is in normal position (para-esophageal hernia) (*b*) Esophageal hiatus hernia in which there is herniation of the greater portion of the stomach through an enlarged esophageal hiatus into the posterior mediastinum and associated elevation of the esophagus (*c*) Slight protrusion of the cardia of the stomach through the hiatus with slight elevation of the lower part of the esophagus to the upper margin of the esophageal hiatus This is a pulsion type of hernia due to an incompetent hiatus (*d*) Protrusion of the cardiac end of the stomach through the esophageal hiatus, there are marked elevation of the esophagus into the posterior mediastinum and an incompetent hiatus.

of swallowing and during respiratory movements. Its greatest strength is in its esophageal attachment, where it acts as an antagonist to the longitudinal muscle fibers of the esophagus, preventing these muscles from pulling the cardia of the stomach through the hiatus

The lower part of the esophagus passes obliquely through the diaphragm and extends below the hiatus for a varying distance of from 0.5 to 1.5 cm, where it joins the stomach at an angle. This junction is the true cardia and normally is always situated below the diaphragm

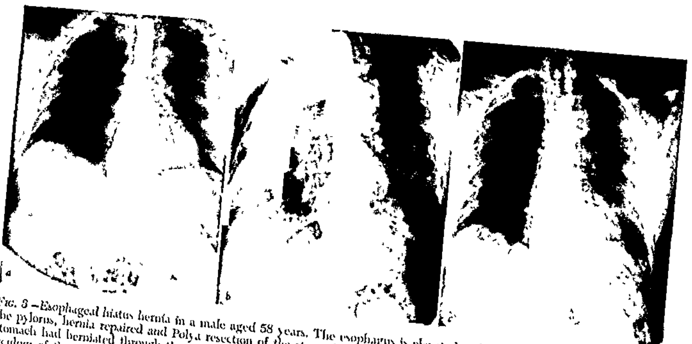


FIG. 8.—Esophageal hiatus hernia in a male aged 58 years. The esophagus is elevated and there is an obstructing ulcer at the pylorus, hernia repaired and Polya resection of the stomach used (*a*) On the first admission the cardiac fourth of the stomach had herniated through the esophageal hiatus with marked elevation and redundancy of the esophagus, diverticulum of the second portion of the duodenum was also present. (*b*) On second admission, after reduction of weight, herniation of about 2 in. (5 1 cm.) of cardia above the esophageal hiatus. Ulcer of the pyloric end of the stomach with partial obstruction (*c*) One year after abdominal repair of the esophageal hiatus hernia and Polya resection of the pyloric two-thirds of the stomach. The entire stomach is below the diaphragm and the anastomosis is free

included under the term "diaphragmatic hernia" but in which there are no hernial sacs would more properly be termed "*eviscerations*" or "*false hernias.*" The presence or absence of a hernial sac cannot be determined by clinical examination. It can be *found only at operation. It is difficult or impossible to make most of these* classifications clinically; accordingly, many of them are *of little practical value.* Diaphragmatic hernias are therefore usually classified in three main groups: (1) congenital, (2) acquired, and (3) traumatic.

From a clinical and surgical standpoint, the history of a preceding injury is helpful in establishing the diagnosis and in determining the type, urgency, and prognosis of the operative treatment. Because of the practical clinical and surgical significance of trauma as an etiologic factor, I have suggested that diaphragmatic hernia be classified into two main groups: nontraumatic and traumatic. I have subdivided these two groups according *to the various types.*

NONTRAUMATIC HERNIA

A nontraumatic diaphragmatic hernia may be congenital or acquired. If it is congenital, the hernia is attributable to embryologic deficiency of the diaphragm or esophagus and usually does not have a hernial sac. If the hernia is acquired after birth, it usually has a hernial sac and is most commonly situated at the esophageal hiatus, the subcostosternal region (foramen of Morgagni) or the posterocostal region (foramen of Bochdalek). The commonest sites of congenital *hernias, in the probable order of frequency of occurrence, are (1) through the* gap left by partial absence of the diaphragm, (2) through the pleuroperitoneal *hiatus, these areas of deficiency of the diaphragm being situated in the posterior* portion of the muscle, (3) through the esophageal hiatus, owing to a deficiency of the circular muscle bundles of the hiatus, (4) through the esophageal hiatus, owing to deficiency of the esophagus which is not elongated sufficiently to extend to the diaphragm, thus causing varying amounts of stomach to remain above the diaphragm depending on the amount of shortening of the esophagus; (5) through an anterior subcostosternal opening (foramen of Morgagni, Larrey's spaces).

I have used the term "pleuroperitoneal hiatus" to designate a congenital complete opening between the pleural and peritoneal cavities due to a lack of fusion of the *septum transversum* and the *pleuroperitoneal membrane.* Hernias occurring through this opening do not have a hernial sac. When there is incomplete muscular formation of the diaphragm in the region of fusion of the pleuroperitoneal membrane and septum transversum but complete covering of the space with pleural or peritoneal membranes which complete the separation of the abdominal from the pleural cavities, this space of muscular deficiency of the diaphragm is called the "foramen of Bochdalek." Hernias occurring through this partially defective *muscular area of the completed* diaphragm would have a hernial sac of peritoneum or pleura I have encountered only one diaphragmatic hernia in this region which had a hernial sac of peritoneum and pleura.

TRAUMATIC HERNIA

Traumatic diaphragmatic hernia may occur in either the right or left half of the diaphragm, but it occurs much more frequently on the left. This type of hernia may be caused by *indirect or direct* injury or by inflammatory necrosis of the

The normal peritoneal covering and attachments of the esophagus and cardia of the stomach, around the esophageal hiatus, are of great importance. The abdominal portion of the esophagus is loosely covered with peritoneum on its anterior and left aspects (Fig. 5). The uppermost part of the stomach is loosely covered, for about 2 cm. anteriorly and 3 cm. posteriorly, where the peritoneum fuses with the serous covering of the gastric wall. The union of these two folds of

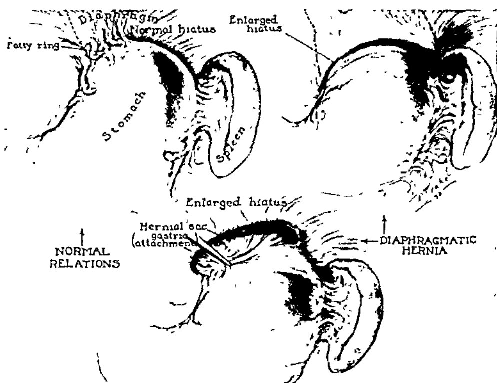


FIG 5 – The anatomic relations at the cardia of a normal stomach compared with those associated with esophageal hiatus diaphragmatic hernia The latter relations are shown with the herniated portion of the stomach in the hernial sac and after it has been withdrawn.

peritoneum forms the gastrophrenic ligament, which fixes the cardiac end of the stomach to the diaphragm, and continues to the left to form the phrenocolic ligament. Beneath this loose peritoneal covering there are a triangular pad of fat and connective tissue and the attachments of the diaphragmatico-esophageal membrane This loose peritoneal attachment around the esophageal hiatus permits flexible movement of the esophagus without pulling on the peritoneum.

CLASSIFICATION OF DIAPHRAGMATIC HERNIA

There are numerous classifications of diaphragmatic hernia which are based on the embryologic and etiologic aspects, pathologic anatomy, the site of the opening in the diaphragm, the presence or absence of a sac, the contents of the hernia, and other factors. As mentioned previously, all true hernias are usually considered to have a sac as one of their component parts, so that many conditions commonly

TABLE I

DATA IN 524 CASES OF DIAPHRAGMATIC HERNIA IN WHICH OPERATION WAS PERFORMED

Site of Opening	*Cases*	*Cause*	*Content of Hernia*	*Cases*
Esophageal hiatus	375	Congenital (history of trauma, 19)	Stomach and omentum	346
			Stomach, omentum, and spleen	7
			Stomach and colon	20
			Stomach, colon, and small bowel	2
Short esophagus type	43	Congenital (20)	Stomach only	42
			Stomach, colon, and small bowel	1
Hiatus, pleuroperitoneal	11	Congenital	Right colon and small bowel	4
			Colon, small bowel, stomach, and spleen	4
			Colon, small bowel, and appendix	2
			Liver only	1
Absence posterior fourth, left side of diaphragm	14	Congenital	Stomach, colon, small bowel, and spleen	5
			Small bowel and colon	2
			Small bowel, colon, spleen, appendix (2), stomach (1), and kidney (7)	7
Foramen of Morgagni (subcostosternal)	14	Congenital (right part of diaphragm, 12, bilateral, 1)	Colon and omentum	10
			Stomach and colon	2
			Omentum only	2
Left portion of diaphragm	65	Trauma (indirect injury, 54, direct injury, 4, inflammatory necrosis, 7)	Stomach only	7
			Stomach and colon	13
			Stomach, colon, small bowel (38), spleen (25), liver (17), and kidney (2)	45
Right portion of diaphragm	2	Trauma (direct)	Stomach, colon, small bowel, liver, gallbladder, and head of pancreas	2
Total	524			524

GENERAL ROENTGENOLOGIC, CLINICAL, AND SURGICAL CONSIDERATIONS OF DIAPHRAGMATIC HERNIA

ROENTGENOLOGIC AND ESOPHAGOSCOPIC MANIFESTATIONS

Roentgenography plays an important role in the recognition and diagnosis of diaphragmatic hernia It is also of great value in determining the size and situation of the defect in the diaphragm, considerations which are of aid in the determination of the method of surgical treatment that is to be instituted.

Kirklin has stated that larger types of diaphragmatic hernias, and especially those in which a large segment of the stomach or bowel is fixed or incarcerated into the thoracic cavity, are strikingly manifest on roentgenologic examination and often the diagnosis is self-evident. But frequently, despite pronounced alteration of the thoracic picture, the diagnosis cannot be established without critical study and small or reducible hernias are likely to escape discovery unless the examiner is alert for clues that will stimulate thorough search.

diaphragm. Hernias caused by indirect injury are usually the result of severe forceful or crushing injuries such as automobile accidents, which is the commonest cause, or being buried in a cave-in of heavy material. In hernias due to indirect injury of the diaphragm, the laceration may occur at any point but it is more likely to occur at the points of embryonic fusion. The commonest sites are the dome and

beyond the midline into the right hemidiaphragm anterior to the circular fibers of the esophageal hiatus. Lacerations occurring in the posterior third of the diaphragm often extend to, but infrequently extend through, the circular muscle of the esophageal hiatus; when the laceration does extend through the esophageal hiatus it is usually through the posterior third of the muscle ring. In some types of injuries, particularly crushing injuries and injuries associated with fracture of the ribs, the laceration of the diaphragm not only extends across the dome but the muscle attachments are also torn from the chest wall making a triangular rent in the diaphragm In this type of injury I have also seen the entire attachment of the left part of the diaphragm torn from the chest wall without any laceration through the dome of the muscle. In case of direct injury of the diaphragm, the hernia may occur at any point and is usually the result of penetrating wounds, such as those inflicted by a gun or a knife

Rupture of the diaphragm may be the result of inflammatory necrosis of which I have found two types: (1) Necrosis which results from a subphrenic abscess which ruptures through the diaphragm into the lung or pleural cavity and from which the patient recovers, but months or often years later herniation of abdominal viscera may occur through the area of rupture in the diaphragm. (2) Necrosis of the diaphragm caused by pressure of hard drainage tubes which have been introduced into empyematic cavities in the lower pleural cavity and which impinge on the diaphragm. In these cases the opening usually is situated in the dome or posterior part of the diaphragm and there is no hernial sac.

In my experience, the commonest types of diaphragmatic hernias, in order of frequency, which require surgical treatment are the different types of esophageal hiatus hernias, hernias due to trauma, indirect or direct, or to inflammatory necrosis, hernias due to absence of a portion of the diaphragm; pleuroperitoneal hiatus hernias, and subcostosternal hernias (foramen of Morgagni).

There are many variations in the positions and types of these hernial openings but the most frequent locations are shown in Fig. 1.

The number of diaphragmatic hernias of each of these types in the 524 cases in which I have operated is shown in Table I. Each of the various types of diaphragmatic hernia presents different clinical manifestations as well as different methods of surgical treatment, which will be discussed with the type of hernia. There are certain general clinical and surgical considerations of diaphragmatic hernia which I shall discuss first although there will be some repetition of detail when each type is described.

the symptoms sufficiently so that surgical treatment for the hernia is not necessary. In other instances the esophagus may be shortened so that the hernia cannot be reduced by surgical procedures.

Carcinoma of the lower end of the esophagus may be associated with diaphragmatic hernia. The presence of these lesions usually can be determined by roentgenographic examination but should be confirmed by esophagoscopic examination with removal of tissue.

Other conditions which are not definitely associated with a hernia may produce clinical symptoms which suggest diaphragmatic hernia and can be distinguished only by roentgenographic or esophagoscopic examination. Some of the commoner conditions of this type are cardiospasm, diverticulum of the lower end of the esophagus, diverticulum of the stomach close to the cardiac orifice, and eventration of the diaphragm.

The roentgenographic differentiation of eventration or elevation of the diaphragm from diaphragmatic hernia may be difficult in some instances. Eventration or elevation of the diaphragm may be due to complete or partial paralysis of the diaphragmatic muscle and may involve the entire diaphragm or only a part of the muscle. This condition is classified by some writers as a type of diaphragmatic hernia but I do not believe it should be classified as a hernia as there is no protrusion of the abdominal viscera through the structure of the second or third ribs; roentgenologic examination will show the abdominal viscera extending to this level in the thoracic cage but the viscera are in the abdominal cavity as they are beneath the diaphragm The most important roentgenologic manifestations of eventration are the visualization of the diaphragm above the abdominal viscera and the paradoxical motion of the diaphragm. In some instances it may be difficult to visualize the position of the diaphragm and its recognition roentgenologically can be aided by the performance of pneumoperitoneum before the examination.

General Clinical Symptoms

The symptoms produced by the different types of diaphragmatic hernia are often complex, because of the various structures involved in the hernia, and depend on the amount of mechanical interference with the function of the herniated abdominal viscera, on the degree of impairment of the normal function of the diaphragm, and on the amount of increased pressure within the thorax, which causes impairment of respiration and circulation.

The clinical syndrome of diaphragmatic hernia may be divided into two main types The first type occurs in cases in which the stomach is the only abdominal organ involved in the hernia The symptoms are those of intermittent and usually progressive incarceration and obstruction of the stomach The commonest type of diaphragmatic hernia in which the stomach is the only abdominal viscus involved is through the esophageal hiatus. This type of hernia, however, may contain various portions of the omentum, depending on the amount of stomach involved Inasmuch as these hernias are progressive, the entire stomach may become involved in the hernia, and the colon may also become incorporated in the hernial sac because of its attachment to the greater curvature of the stomach. More rarely the spleen may become involved because of its attachment to the cardia of the stomach In cases in which the colon is involved, there may be addi-

Among signs suggestive of hernia that may be elicited in routine examination of the stomach, displacement of the lower segment of the esophagus is significant and is of common occurrence. In many cases, as the mixture of barium passes through the gullet, it becomes evident that the lower portion of the esophagus is displaced mesially and that it describes a hooklike curve. In other instances the terminal segment is tortuous but not dilated. In still other cases the segment is angulated. Congenital shortening of the esophagus is noted on roentgenologic examination in rare instances. Undue retardation of the barium stream at the esophageal hiatus is another potential indication of hernia and occurs in many cases.

Scarcely second in importance among signs suggestive of hernia is the observation that the level of the gastric contents is above that of the esophageal aperture. Diaphragmatic hernia is the most probable cause of this condition and this sign aids in distinguishing hernia from eventration, for in the latter condition the two levels coincide. What apparently is a high hourglass contraction of the stomach with a visible niche at the site of constriction often is, in fact, hernia of the stomach through the diaphragm, and the ulcer is merely a complication. In many cases of hernia the symptoms are chiefly or solely thoracic and roentgenologic examination of the thorax is demanded first. Again, hernias involving the stomach and colon may be obvious, but in many cases the manifestations, although pronounced, are not diagnostic. In such cases hernia always should be taken into consideration and appropriate examination should be requested.

Reducible hernias, such as the para-esophageal variety, usually can be revealed at examination with the patient in the vertical position by pressing the stomach upward or they may be suspected by the presence of one or more of the signs already described, but roentgenoscopic examination in the horizontal position is always necessary to confirm the diagnosis and to determine the extent of herniation. In no instance can hernia of the colon be excluded confidently without employing a barium enema, and when only the small bowel is implicated, repeated observations after the patient has ingested an opaque meal are necessary for diagnosis. In the rare cases of hernia through the right arch of the diaphragm, a portion of the liver usually projects through the breach and is likely to be mistaken for a neoplasm. On the whole, however, few diaphragmatic hernias should elude roentgenologic disclosure and specific diagnosis.

Roentgenography not only plays an important role in the recognition of diaphragmatic hernia but also is of equal value in distinguishing this from other conditions in which the clinical symptoms often simulate those of diaphragmatic hernia. It is also of value in determining the presence of any obstructive lesion of the esophagus. The lesions are more accurately determined, however, by endoscopic examination of the esophagus than by roentgenography.

It is essential that all patients who have diaphragmatic hernia should have thorough esophagoscopic examination before surgical intervention. Strictures of the lower part of the esophagus associated with the esophageal hiatus type of diaphragmatic hernia are fairly common; these strictures often result from cicatricial contraction of a traumatic ulcer caused by the hernia. It is important that these associated strictures be recognized before surgical treatment is considered for the hernia, because in many instances dilatation of the esophagus will relieve

the symptoms sufficiently so that surgical treatment for the hernia is not necessary. In other instances the esophagus may be shortened so that the hernia cannot be reduced by surgical procedures.

Carcinoma of the lower end of the esophagus may be associated with diaphragmatic hernia. The presence of these lesions usually can be determined by roentgenographic examination but should be confirmed by esophagoscopic examination with removal of tissue.

Other conditions which are not definitely associated with a hernia may produce clinical symptoms which suggest diaphragmatic hernia and can be distinguished only by roentgenographic or esophagoscopic examination. Some of the commoner conditions of this type are cardiospasm, diverticulum of the lower end of the esophagus, diverticulum of the stomach close to the cardiac orifice, and eventration of the diaphragm.

The roentgenographic differentiation of eventration or elevation of the diaphragm from diaphragmatic hernia may be difficult in some instances. Eventration or elevation of the diaphragm may be due to complete or partial paralysis of the diaphragmatic muscle and may involve the entire diaphragm or only a part of the muscle. This condition is classified by some writers as a type of diaphragmatic hernia but I do not believe it should be classified as a hernia as there is no protrusion of the abdominal viscera through the structure of the second or third ribs; roentgenologic examination will show the abdominal viscera extending to this level in the thoracic cage but the viscera are in the abdominal cavity as they are beneath the diaphragm. The most important roentgenologic manifestations of eventration are the visualization of the diaphragm above the abdominal viscera and the paradoxical motion of the diaphragm. In some instances it may be difficult to visualize the position of the diaphragm and its recognition roentgenologically can be aided by the performance of pneumoperitoneum before the examination.

General Clinical Symptoms

The symptoms produced by the different types of diaphragmatic hernia are often complex, because of the various structures involved in the hernia, and depend on the amount of mechanical interference with the function of the herniated abdominal viscera, on the degree of impairment of the normal function of the diaphragm, and on the amount of increased pressure within the thorax, which causes impairment of respiration and circulation.

The clinical syndrome of diaphragmatic hernia may be divided into two main types. The first type occurs in cases in which the stomach is the only abdominal organ involved in the hernia. The symptoms are those of intermittent and usually progressive incarceration and obstruction of the stomach. The commonest type of diaphragmatic hernia in which the stomach is the only abdominal viscus involved is through the esophageal hiatus. This type of hernia, however, may contain various portions of the omentum, depending on the amount of stomach involved. Inasmuch as these hernias are progressive, the entire stomach may become involved in the hernia, and the colon may also become incorporated in the hernial sac because of its attachment to the greater curvature of the stomach. More rarely the spleen may become involved because of its attachment to the cardia of the stomach. In cases in which the colon is involved, there may be addi-

tional symptoms of partial or complete intestinal obstruction. If the hernia progresses and more of the abdominal viscera are involved, it becomes a diaphragmatic hernia of the second type.

The second type consists of those cases in which multiple abdominal viscera are involved in the hernia These hernias are usually of traumatic origin and are caused by laceration of a normal diaphragm. They also may be of congenital origin, however, and may result from congenital structural deficiency of the diaphragm. The symptoms in these cases are more varied and severer than those of the first type because of the multiple structures involved and are often more acute in onset. The initial symptoms may be those of acute intestinal or gastric obstruction or severe hemorrhage.

The clinical recognition of diaphragmatic hernia on the basis of subjective symptoms alone is often difficult because the symptoms vary, and frequently simulate those of other organic diseases of the abdomen and thorax. This, I believe, is the most important clinical consideration of diaphragmatic hernia. This is also of surgical importance as the clinical symptoms may simulate those of other organic diseases so closely that surgical measures may be instituted for conditions other than the hernia. It is particularly so in those types of hernia which are progressive and the symptoms of which vary with the type and degree of herniation so that several clinical diagnoses can be made at different times because of the changing symptoms

It is to be remembered that patients presenting symptoms of diaphragmatic hernia may also have symptoms, due to other unrelated disease, which confuse the clinical manifestations. I have operated on a number of patients who have had an associated duodenal ulcer with obstruction, gastric ulcer with obstruction, and carcinoma of the pyloric end of the stomach with obstruction, as well as a number of patients who also had cholelithiasis. In cases in which there is cholecystic disease as well as diaphragmatic hernia, I think it is advisable to operate for the cholecystic disease before the hernia is repaired (unless the hernia is incarcerated or obstruction is present) because of the clinical danger of an acute condition arising from the cholecystic disease that might produce a recurrence of the hernia from severe attacks of vomiting. If a gastric or duodenal ulcer or a gastric carcinoma which obstructs the pyloric end of the stomach is associated with diaphragmatic hernia, operation should be performed for both of these conditions at the same time. I do not believe, however, that operation should be performed for an associated condition at the same time that the diaphragmatic hernia is repaired if operation can be safely deferred.

General Surgical Considerations

From the standpoint of treatment, diaphragmatic hernia is primarily a mechanical condition, and the only treatment which will relieve the condition is operative repair or reconstruction of the abnormal opening in the diaphragm after replacement of the herniated viscera into the abdomen. The indications for surgical intervention and methods and technic of surgical procedures depend on the type, situation, and size of the defect in the structure of the diaphragmatic muscle, the kind and amount of abdominal viscera involved in the hernia, and whether or not the viscera are enclosed in a hernial sac.

The surgical approach to any of the different types of diaphragmatic hernia may be through the thorax or through the abdomen. There are some types of hernia with a hernial sac, such as esophageal hiatus hernia and subcostosternal hernia, which in my opinion can be more adequately and safely repaired through an abdominal than through a thoracic approach. In other types of hernia which do not have a hernial sac, such as those due to traumatic rupture or congenital absence of the diaphragm, it is the surgeon's privilege to choose whether the approach will be made through the thorax or through the abdominal cavity.

In the repair of all hernias through the right portion of the diaphragm, I prefer the thoracic approach because the large, right lobe of the liver makes the abnormal opening in the diaphragm inaccessible from the abdominal approach. In most hernias through the left side of the diaphragm, I prefer the abdominal approach.

The technical difficulties of adequate exposure of the hernial openings through the left portion of the diaphragm and the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of these hernial openings is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the incision. The spleen is often adherent to the posterior part of the diaphragm and hernial openings but usually can be separated from these structures by blunt dissection. In some instances the spleen has been so traumatized by the injury, and so bound into its abnormal position by adhesions, that it cannot be separated from the hernial opening without seriously injuring it. This occurs fairly commonly in traumatic types of hernias and occasionally in esophageal hiatus hernia. In these cases splenectomy is necessary.

Interruption of Phrenic Nerve

Paralysis of the diaphragm, produced by temporary or permanent interruption of the phrenic nerve, is of value as a procedure preliminary to radical operative repair of many different types of diaphragmatic hernia. In some types, usually the esophageal hiatus hernia, in which radical operative repair is inadvisable because of another serious unassociated disease, or poor general condition of elderly patients, or when there is marked spasm or contraction of the diaphragmatic opening, interruption of the phrenic nerve may be used as the only surgical therapeutic measure. In many instances utilization of this procedure will only greatly relieve the patient of subjective symptoms, although in some instances the hernia may increase in size if other therapeutic measures such as weight reduction are not carried out. In most instances in which interruption of the phrenic nerve is utilized as an auxiliary procedure, preliminary to radical operative repair of the hernia, I prefer, first, to perform temporary interruption of the nerve by crushing it in the cervical or thoracic regions, because in many instances it may not be necessary for the resultant paralysis to be permanent. Function is usually re-established within three to six months In cases in which re-establishment of function of the diaphragm is not desirable because of the danger of recurrence of the hernia, the paralysis can be made *permanent* by cutting or partially resecting the phrenic nerve. As a procedure preliminary to radical surgical treatment, interruption of the phrenic nerve is often of value in the treatment

of incarcerated and strangulated hernias because it prevents spasm of muscle and causes relaxation of the hernial ring.

Paralysis of the diaphragm is of great advantage in the closure of large hernial openings when there is considerable loss of structure of the diaphragm, as is usually found in traumatic or congenital hernias. In this type of hernia, interruption of the phrenic nerve may be done in the cervical region preliminary to the abdominal repair of the hernia or the nerve may be crushed or cut along its course in the mediastinum through the hernial orifice at the time of operation. In cases in which the operation is done through a thoracic approach interruption of the phrenic nerve is done transpleurally just above the diaphragm. The relaxation of the diaphragm after this procedure permits the structural defect to be closed without tension and, in cases of traumatic hernia in which the diaphragm has been torn from the thoracic wall, it permits the diaphragm to be sutured to the intercostal muscles

Closure of Hernial Opening

The most satisfactory materials for the suturing of hernial openings are silk and living sutures of fascia lata. For infants it may be necessary to use silk only. For adults living sutures of fascia lata can be removed from the thigh with a Masson fascia stripper. This instrument consists of a tube within a tube with a cutting edge and is so designed that the fascia may be removed through a small incision in the upper part of the thigh and the lower end of the fascia may be cut in situ by sliding the cutting edge through the lower end of the fascia. In this way a second lower incision to cut the fascia is not necessary. The amount to be removed depends on the type of hernia to be repaired. One or two strips of fascia are sufficient for esophageal hiatus hernias. For the larger hernias of the traumatic type, wider strips of fascia are removed because three or four strips may be required to complete the closure of the rent in the diaphragm. For congenital hernias in which there is structural defect, a large amount of fascia is often necessary to close the defect After the defect is closed the fascia should be fixed with silk. The cut margins of the fascia in the thigh should be closed if possible with interrupted catgut while the incision is closed with interrupted dermal sutures.

Anesthesia

The method of administration of the anesthetic agent depends on the type of hernia which is present. In all cases in which there is no hernial sac and in which there is a direct communication between the abdominal and thoracic cavities, I prefer intratracheal administration of the anesthetic agent by means of a positive machine The use of the intratracheal tube makes it possible to maintain adequate oxygenation at all times and under all circumstances because it insures an adequate airway and mucus and secretions can be aspirated through the tube. It is also an added protection against respiratory dysfunction arising from collapse of the lung The anesthetic agent to be used depends on the indications presented in each case I have used ether, ethylene, and cyclopropane. I prefer cyclopropane in combination with ether, as this combination permits greater safety in producing surgical relaxation with adequate oxygenation than when these anesthetic agents

ESOPHAGEAL HIATUS HERNIA

Herniation of abdominal viscera through the esophageal hiatus is the commonest type of diaphragmatic hernia. Hernias of this type may be present at birth but are less common than other types of congenital diaphragmatic hernias. They are the commonest type of diaphragmatic hernia affecting adults. These hernias are of considerable general interest because of their relatively frequent occurrence; their indefinite causation, the variation of the relationship between the defective esophageal hiatus and the esophagus as well as the structures involved in the different types; the progressive character of their development; the varied and complex symptoms produced by them, which may simulate those of other organic disease, and because of their treatment, which may be conservative if the hernias are small and the symptoms mild, but which may require surgical intervention if the hernias are large.

Because several types of esophageal hiatus hernias may be encountered, many different terms and classifications, based on etiologic aspects, pathologic anatomy, roentgenologic findings, or clinical findings, have been suggested. The multiplicity of terms which has been used undoubtedly has led to considerable misunderstanding as to the various types of hernia found. I believe that in classifying these hernias an actual description of the findings should be made so that there will be no misunderstanding as to the structures involved. I believe that most esophageal hernias are fundamentally congenital in origin in that there is a congenital malformation of the esophageal hiatus and the diaphragmatico-esophageal attachments at the lower end of the esophagus and the cardiac portion of the stomach. However, in most instances the hernia does not occur until later in life, usually beyond middle age.

Anatomic and Embryologic Aspects

The diaphragmatico-esophageal membrane and the loose attachment of the peritoneum at the cardia have considerable bearing on the occurrence of esophageal hiatus hernias It is probable that the hiatal hernias of elderly people, which are accompanied by insufficiency of the hiatus, are attributable to atrophy of this protective elastic membrane, particularly in cases in which there is an abnormally large hiatus The elastic membrane has been sufficient during the prime of life to protect the opening but, as the atrophy associated with advancing years develops, the stomach is permitted to protrude through the large hiatus to a position above the diaphragm. It is probable, in such cases, that this herniation would have occurred earlier in life had abnormal stress been applied, such as trauma, respiratory difficulty, or marked increase of intra-abdominal pressure. The elastic and fibrous membrane forms one of the coverings of the hernial sac in the smaller types of hernia. In large hernias this membrane seems to be pushed forward and there is no barrier to the peritoneal sac, which enters the posterior portion of the mediastinum In these cases the entire stomach often herniates into the thorax.

The loose attachment of the peritoneum around the hiatus may be a factor in the formation of hiatal hernias, since it permits the beginning of the herniation of the cardiac end of the stomach and the formation of the hernial sac.

In all true hernias this loose peritoneal fold fuses with the serosa farther down on the cardia of the stomach than is normal. The peritoneum does not extend around the greater curvature of the stomach to the posterior wall to form the gastrophrenic ligament but fuses with the serosa of the anterior wall, so that there is no gastrophrenic ligament and only a short phrenicolienal ligament. This places the spleen close to the left margin of the hiatus, thus permitting the upper part of the cardiac end of the stomach to be abnormally free posteriorly beneath the enlarged esophageal hiatus.

The consistency with which the surgeon finds abnormal attachments of the peritoneal fold and of the gastrophrenic ligament to the cardiac end of the stomach and abnormal enlargement of the muscular ring of the esophageal hiatus, suggests that this particular type of hernia has an embryologic cause and results from delayed descent of the esophagus as related to the formation of the lumbar portion of the diaphragm.

Inasmuch as the stomach descends behind the septum transversum, if its descent is delayed the lumbar portion of the diaphragm will be imperfectly developed and the esophageal hiatus will be formed around the cardiac end of the stomach instead of around the esophagus. This will result in an abnormally large hiatus with deficiency both in the muscle ring and in the attachments of the diaphragmatico-esophageal membrane. The degree of deficiency depends on the amount of gastric anlage in the thorax at the time of muscularization of the lumbar portion of the diaphragm. In rare instances the stomach may remain in the elevated position as a result of a congenitally short esophagus and a partial thoracic stomach will result. In most instances the esophagus continues to elongate normally, thus placing the stomach below the diaphragm. This abnormal position of the stomach will cause an abnormal enlargement of the esophageal hiatus, with a wide space between the margin of the muscle and the wall of the esophagus. It also will result in imperfect fixation of the elastic membrane to the esophagus and stomach and an abnormally large peritoneal fold which will extend well down on the cardia of the stomach. This abnormal relationship will permit much more flexibility of the esophagus in the enlarged hiatus than is normal. The more defective the formation of the hiatus, the more likely it is that herniation of the stomach will occur later in life. The true congenital hernia present at birth may be explained in the same way but it is probable that persistence of the dorsopleural recess may be a factor in the origin of congenital hernias.

Classification

Esophageal hiatus hernia is the commonest kind of hernia which occurs through the diaphragm found among adult persons. This type of hernia is slowly progressive and constitutes a sliding herniation of the stomach into the posterior part of the mediastinum. It may push into either or both sides of the thoracic cavity but does not enter the pleural cavity. The stomach usually is the only abdominal viscus involved in the hernia, but rarely the colon is the only abdominal viscus involved. This type of hernia may progress until the entire stomach is contained in the

hernial sac, and the colon, omentum, and occasionally the spleen may also be drawn into the hernial sac.

I believe it best to classify all true hernias through the esophageal hiatus under the one term "esophageal hiatus diaphragmatic hernia." True esophageal hiatus hernias can be divided into two types. In the first type the esophagus is of normal length and its lower end is not elevated above the diaphragm, but a portion of the stomach has herniated into the posterior mediastinum, beside the esophagus. This type of hernia is often designated as para-esophageal hiatus hernia. The hernias are usually small to moderate in size and rarely involve more than a fourth to a half of the cardiac end of the stomach, which is contained in the hernial sac. They constitute about one-fourth of the esophageal hiatus hernias on which I have operated (Fig. 2).

In the second type of hiatal hernia, the esophagus is of normal length but its lower end is elevated above the level of the diaphragm and the herniated stomach is in the posterior mediastinum. The hernias are usually larger than those of the first type and from a third of the stomach to the entire stomach, with a portion of the omentum and occasionally a portion of the colon, is within the hernial sac. These hernias usually fill the entire mediastinum and generally project into the left side of the thoracic cavity but they may project into the right side of the thoracic cavity or into both sides Hernias of this type constitute about three-fourths of the esophageal hiatus hernias on which I have operated (Fig. 3).

I believe that the essential difference between these two types is one of degree rather than any fundamental difference of origin. Inasmuch as these hernias are progressive in character and are in reality a sliding type of hernia, hernias of the first type may ultimately develop into those of the second type as more of the stomach becomes included in the hernial sac In many cases of esophageal hiatus hernias the lower end of the esophagus is dilated. This is usually more marked in the larger hiatal hernias (Fig 4).

With the more frequent roentgenologic recognition of small hiatal hernias in the last few years, two additional types have been recognized, which may be considered pulsion types of esophageal hiatus hernias due to incompetent hiatal muscle. In these types a small portion of the cardiac end of the stomach projects through the esophageal hiatus They are probably attributable to atrophy of the elastic fibers of the diaphragmatico-esophageal membrane together with relaxation of the circular muscle which surrounds the esophageal opening, resulting in an incompetent hiatus. Recognition and differentiation of these two types are [illegible] The establishment of the [illegible], which is often essential in [illegible] nore commonly encountered among elderly people In many instances the finding of these hernias is incidental, as the patients do not present any subjective symptoms, however, in some instances the symptoms may be severe and may not respond to conservative therapeutic measures. In the latter cases, surgical intervention is necessary to relieve the symptoms.

Hernias of the third type closely simulate the para-esophageal type of hernia except that they are relatively small. There is the beginning formation of a definite hernial sac. The esophagus is only slightly elevated, the abdominal portion being

The loose attachment of the peritoneum around the hiatus may be a factor in the formation of hiatal hernias, since it permits the beginning of the herniation of the cardiac end of the stomach and the formation of the hernial sac.

In all true hernias this loose peritoneal fold fuses with the serosa farther down on the cardia of the stomach than is normal. The peritoneum does not extend around the greater curvature of the stomach to the posterior wall to form the gastrophrenic ligament but fuses with the serosa of the anterior wall, so that there is no gastrophrenic ligament and only a short phrenicolienal ligament. This places the spleen close to the left margin of the hiatus, thus permitting the upper part of the cardiac end of the stomach to be abnormally free posteriorly beneath the enlarged esophageal hiatus.

The consistency with which the surgeon finds abnormal attachments of the peritoneal fold and of the gastrophrenic ligament to the cardiac end of the stomach and abnormal enlargement of the muscular ring of the esophageal hiatus, suggests that this particular type of hernia has an embryologic cause and results from delayed descent of the esophagus as related to the formation of the lumbar portion of the diaphragm.

Inasmuch as the stomach descends behind the septum transversum, if its descent is delayed the lumbar portion of the diaphragm will be imperfectly developed and the esophageal hiatus will be formed around the cardiac end of the stomach instead of around the esophagus. This will result in an abnormally large hiatus with deficiency both in the muscle ring and in the attachments of the diaphragmatico-esophageal membrane. The degree of deficiency depends on the amount of gastric anlage in the thorax at the time of muscularization of the lumbar portion of the diaphragm. In rare instances the stomach may remain in the elevated position as a result of a congenitally short esophagus and a partial thoracic stomach will result. In most instances the esophagus continues to elongate normally, thus placing the stomach below the diaphragm This abnormal position of the stomach will cause an abnormal enlargement of the esophageal hiatus, with a wide space between the margin of the muscle and the wall of the esophagus It also will result in imperfect fixation of the elastic membrane to the esophagus and stomach and an abnormally large peritoneal fold which will extend well down on the cardia of the stomach. This abnormal relationship will permit much more flexibility of the esophagus in the enlarged hiatus than is normal. The more defective the formation of the hiatus, the more likely it is that herniation of the stomach will occur later in life The true congenital hernia present at birth may be explained in the same way but it is probable that persistence of the dorso-pleural recess may be a factor in the origin of congenital hernias.

Classification

Esophageal hiatus hernia is the commonest kind of hernia which occurs through the diaphragm found among adult persons. This type of hernia is slowly progressive and constitutes a sliding herniation of the stomach into the posterior part of the mediastinum. It may push into either or both sides of the thoracic cavity but does not enter the pleural cavity The stomach usually is the only abdominal viscus involved in the hernia, but rarely the colon is the only abdominal viscus involved. This type of hernia may progress until the entire stomach is contained in the

the shortening of the esophagus is not too great. By complete and permanent interruption of the phrenic nerve, the diaphragm usually can be elevated from 2 to 5 cm. and then by complete separation of the attachment of the esophagus from

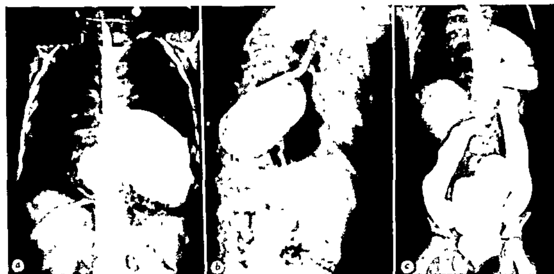


Fig 6.—Esophageal hiatus diaphragmatic hernia with intrathoracic stomach, partial shortening of the esophagus, and herniation of the transverse colon and loop of the small intestine into the posterior mediastinum of a five year old boy (*a*), (*b*), and (*c*) Taken on admission of the patient, showing herniation of the entire stomach and transverse colon into the lower left portion of the thoracic cavity

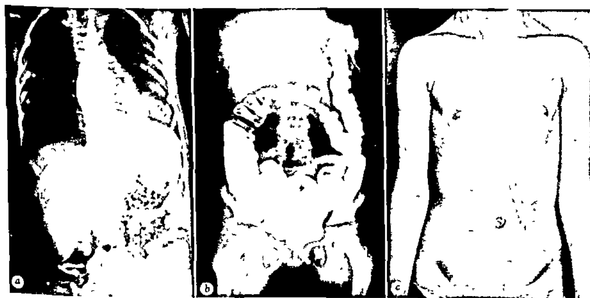


Fig 7—The same patient as shown in Fig 6, one year after abdominal repair of the hernia The entire stomach and colon are in normal position below the diaphragm and the wound is entirely healed There were no symptoms at this time

the attachments around the esophageal hiatus, from 2 to 3 cm. of the esophagus can be drawn down into the abdomen The elevation of the diaphragm and the pulling down of as much of the esophagus into the abdomen as is possible will

elevated to the superior border of the diaphragm. The hernia may remain small or it may develop into a true para-esophageal hernia.

In the fourth type, there is incompetency of the entire hiatus with a funnel-like protrusion of the cardiac end of the stomach above the diaphragm and a comparable elevation of the esophagus, which enters the apex of the protruded portion of the stomach. This type does not have a true hernial sac and may not be considered a true hernia. It must be distinguished in diagnosis from a congenital short esophagus with partial thoracic stomach and from dilatation of the lower end of the esophagus. This is best accomplished by an esophagoscopic examination to determine the length of the esophagus.

Short Esophagus with Thoracic Stomach

Herniations of the stomach through the esophageal hiatus due to a short esophagus are of two main types: the congenital type and the acquired type. The congenital type comprises those cases in which the esophagus has not elongated sufficiently to reach the diaphragm and varying amounts of the stomach are suspended above the diaphragm. Ulceration usually is present at the esophagogastric junction and there are varying degrees of stenosis. This type is not common and constitutes only about 5 per cent of hernias due to a short esophagus. The acquired type constitutes the remaining 95 per cent of the cases. In some of these cases the cause of the shortened esophagus cannot be definitely established but in most cases it results from cicatricial contraction of the esophagus secondary to inflammatory changes which result from various causes. Some of the commoner of these causes are esophageal hiatus hernia with regurgitation of gastric juices into the esophagus, peptic esophageal ulceration, excessive vomiting, reflex spasm of cardia and esophagus, traumatic ulceration associated with hiatal hernias sliding back and forth in the hernial opening, trauma to the esophagus as the result of permitting transesophageal tubes to remain in place for long periods of time, and malignant lesions of the esophagus (Figs 6 and 7).

Radical surgical treatment of all types of short esophageal hiatus hernia present an entirely different technical problem from that of hiatal hernia with an esophagus of normal length and the results of radical operation are much less satisfactory In most of these cases the chief subjective symptom is dysphagia caused by stenosis of the esophagus, and this is best relieved by dilatations of the esophagus only. Radical operative procedures should be carried out only if the patient is not relieved by dilatations and conservative measures of dietary regulation of weight if he is overweight

The essential considerations in the surgical treatment of esophageal hiatus hernia with elevation of the esophagus are (1) replacement of the herniated stomach into the abdomen and bringing the esophagus to, or below, the diaphragm; (2) removal or obliteration of the hernial sac, and (3) repair and reconstruction of the esophageal hiatus at a higher level on the esophagus, 2 or 3 cm. above the cardiac junction Congenital short esophagus with partial thoracic stomach is not a true hernia through the diaphragm, in that the stomach has never been in its normal position below the diaphragm because of the shortened esophagus. The surgical problem in these cases is that of reconstructing the diaphragm over the elevated portion of the stomach, this can be accomplished if

the shortening of the esophagus is not too great. By complete and permanent interruption of the phrenic nerve, the diaphragm usually can be elevated from 2 to 5 cm. and then by complete separation of the attachment of the esophagus from



partial shortening intestine into the admission of the patient, showing herniation of the entire stomach and transverse colon into the lower left portion of the thoracic cavity

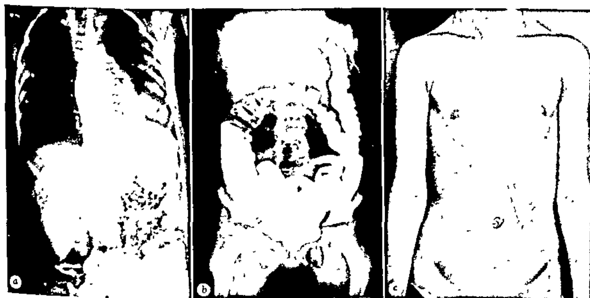


Fig 7 —The same patient as shown in Fig 6, one year after abdominal repair of the hernia. The entire stomach and colon are in normal position below the diaphragm and the wound is entirely healed There were no symptoms at this time.

the attachments around the esophageal hiatus, from 2 to 3 cm. of the esophagus can be drawn down into the abdomen. The elevation of the diaphragm and the pulling down of as much of the esophagus into the abdomen as is possible will

permit closure of the esophageal hiatus around the lower end of the esophagus and placement below the diaphragm of what was formerly the thoracic portion of the stomach. If the shortening of the esophagus is more than 5 to 6 cm. it may not be possible to obtain sufficient elevation of the diaphragm to reconstruct the esophageal hiatus above the stomach. Stricture at the esophagogastric junction is associated fairly often with congenital short esophagus as well as with other types of short esophagus. In most instances repeated dilatations of the stricture will relieve the obstruction. If obstruction cannot be relieved in these cases by dilatation, transthoracic resection of the esophagus may be required with reimplantation of the esophagus into the wall of the stomach.

Dilatation of the Lower End of the Esophagus with Relaxation of the Cardia of the Stomach

This condition fairly commonly simulates esophageal hiatus hernias of the pulsion types both roentgenologically and clinically. In order to establish a definite diagnosis it is usually necessary to examine the esophagus with an esophagoscope as well as to carry out roentgenologic examination. At the time of the esophagoscopic examination, a specimen of tissue can be removed from the wall to determine whether it is squamous cell epithelium of the esophagus or gastric mucosa of the stomach. It is important to distinguish dilatations of the lower part of the esophagus from hiatal hernias, as surgical intervention is not indicated in cases of dilatation of the esophagus.

Symptoms of Esophageal Hiatus Hernia

The symptoms of esophageal hiatus hernia may begin at birth or at any time during later life. Owing to the progressive character of these hernias the symptoms vary as the hernia becomes larger, depending on the degree and type of herniation, so that several clinical diagnoses can be made in the same case because of the changing symptoms. Accordingly, the condition may be termed the "masquerader of the upper part of the abdomen." The commonest erroneous diagnoses, in order of frequency, were cholecystitis, cholelithiasis, gastric ulcer, duodenal ulcer, hyperacidity, secondary anemia, cardiac disease, carcinoma of the cardia, stricture of the esophagus, appendicitis, and intestinal obstruction.

The chief symptoms of esophageal hiatus hernia are pain, distress, gaseous eructation, regurgitation of food, vomiting, dyspnea, hemorrhage, weakness, anemia, and palpitation of the heart. At the onset the symptoms are usually mild; they consist of epigastric distress that is projected through to the back and which comes on in the course of, or shortly after, a heavy meal. Such attacks, however, may be brought on by taking anything into an empty stomach, such as a cupful of coffee. The chief symptom may be regurgitation of small or large quantities of food or gastric juice on stooping or soon after meals. The attacks are usually similar to one another in character but vary a great deal in intensity, depending on the amount of stomach that becomes incorporated in the hernia and the degree of interference with the diaphragm, as well as the size of the hernial orifice and the occurrence of associated complications such as traumatic ulcer and incarceration of the stomach.

As more of the stomach becomes incorporated in the hernia, the attacks become

severer; the pain is projected straight through to the back and to the lower left side of the thorax, is more marked to the left of the spinal column than elsewhere in the back, and often appears between the scapulae. This pain may be agonizing and difficulty is experienced in belching of gas and vomiting because of spasm of the diaphragm and reflex cardiospasm. The spasm of the diaphragm produces an hourglass deformity of the stomach, which interferes with emptying of the upper loculus and causes increased intragastric pressure. The pressure of the herniated portion of th [illegible] belching of [illegible] referred phr[illegible] the arm. The increased pressure within the thorax causes cardiac embarrassment, with palpitation and tachycardia. The pressure on the lung and the interference with the motion of the diaphragm cause dyspnea. These symptoms are augmented when the patient lies down and in severer instances of the condition it is necessary for patients to sit up to breathe. The attacks may last for a few minutes to several hours and occasionally they are considered to be caused by coronary sclerosis or by myocardial disease. The patient usually is completely relieved by vomiting, although attacks often recur immediately after food is taken.

An interval of weeks or months often occurs between attacks. It is probable that during the interval between attacks the stomach is not incorporated in the hernial ring but is situated in its normal position below the diaphragm. When the attacks become more or less constant, the constancy usually indicates that the stomach has become fixed in the thorax by adhesions. All the early symptoms of pressure are augmented during the attacks. There is loss of weight arising from the patient's inability to retain food and from marked restriction of diet resulting from the patient's fear of bringing on an acute attack, which may be termed "food fear." The vomiting is severer and often of the retention type. During severe vomiting, the vomitus may contain blood. If the attacks are of long standing, the patient fairly commonly has a burning sensation in the epigastrium after meals, which is relieved by taking small quantities of food. If a large amount of food is taken, it may bring on one of the attacks that is associated with incarceration of the stomach. Many of these patients present a comparatively typical syndrome of peptic ulcer, are given medical care, and obtain partial relief because they have taken a restricted amount of food at frequent intervals.

Hemorrhage is a fairly common sign. It is caused by a traumatic ulcer, which is usually situated in the lower end of the esophagus close to its juncture with the stomach and may be found in that portion of the stomach in the hernial sac near the lesser curvature. These traumatic ulcers result from the to-and-fro action of the stomach in the hernial ring when the hernia is small as well as from the forceful pressure exerted on the large distorted and congested stomach during the attacks of vomiting when the hernia is large. There is also the additional factor of regurgitation of gastric juice into the lower part of the esophagus, which produces esophagitis.

Bleeding from traumatic erosions may be severe and hematemesis or melena is often one of the chief signs. This type of hemorrhage is most commonly noted in those cases in which there occur repeated severe attacks of obstruction resulting from incarceration of the stomach in the hernial sac. In some instances the hemor-

permit closure of the esophageal hiatus around the lower end of the esophagus and placement below the diaphragm of what was formerly the thoracic portion of the stomach. If the shortening of the esophagus is more than 5 to 6 cm. it may not be possible to obtain sufficient elevation of the diaphragm to reconstruct the esophageal hiatus above the stomach. Stricture at the esophagogastric junction is associated fairly often with congenital short esophagus as well as with other types of short esophagus. In most instances repeated dilatations of the stricture will relieve the obstruction. If obstruction cannot be relieved in these cases by dilatation, transthoracic resection of the esophagus may be required with reimplantation of the esophagus into the wall of the stomach.

Dilatation of the Lower End of the Esophagus with Relaxation of the Cardia of the Stomach

This condition fairly commonly simulates esophageal hiatus hernias of the pulsion types both roentgenologically and clinically. In order to establish a definite diagnosis it is usually necessary to examine the esophagus with an esophagoscope as well as to carry out roentgenologic examination. At the time of the esophagoscopic examination, a specimen of tissue can be removed from the wall to determine whether it is squamous cell epithelium of the esophagus or gastric mucosa of the stomach. It is important to distinguish dilatations of the lower part of the esophagus from hiatal hernias, as surgical intervention is not indicated in cases of dilatation of the esophagus.

Symptoms of Esophageal Hiatus Hernia

The symptoms of esophageal hiatus hernia may begin at birth or at any time during later life. Owing to the progressive character of these hernias the symptoms vary as the hernia becomes larger, depending on the degree and type of herniation, so that several clinical diagnoses can be made in the same case because of the changing symptoms Accordingly, the condition may be termed the "masquerader of the upper part of the abdomen." The commonest erroneous diagnoses, in order of frequency, were cholecystitis, cholelithiasis, gastric ulcer, duodenal ulcer, hyperacidity, secondary anemia, cardiac disease, carcinoma of the cardia, stricture of the esophagus, appendicitis, and intestinal obstruction.

The chief symptoms of esophageal hiatus hernia are pain, distress, gaseous eructation, regurgitation of food, vomiting, dyspnea, hemorrhage, weakness, anemia, and palpitation of the heart. At the onset the symptoms are usually mild; they consist of epigastric distress that is projected through to the back and which comes on in the course of, or shortly after, a heavy meal. Such attacks, however, may be brought on by taking anything into an empty stomach, such as a cupful of coffee. The chief symptom may be regurgitation of small or large quantities of food or gastric juice on stooping or soon after meals. The attacks are usually similar to one another in character but vary a great deal in intensity, depending on the amount of stomach that becomes incorporated in the hernia and the degree of interference with the diaphragm, as well as the size of the hernial orifice and the occurrence of associated complications such as traumatic ulcer and incarceration of the stomach

As more of the stomach becomes incorporated in the hernia, the attacks become

includes those cases in which the symptoms are moderate and the hernias are of moderate size; in many of the cases in this group, conservative treatment, such as regulation of diet and reduction of weight, is sufficient to relieve the symptoms. The third group includes those cases in which there is no response to conservative measures, in these cases the hernias usually are large, and in many cases, in my experience, there are complications, such as incarceration of the stomach with varying degrees of obstruction of the stomach and lower portion of the esophagus, gastric erosion, ulceration, or esophagitis often associated with hemorrhages. In this group of cases the only treatment that assures relief of symptoms is operative repair of the hernia.

In all cases in which a third or more of the stomach is involved in the hernia, surgical intervention should be considered, because the condition is progressive and usually the progressive enlargement becomes more rapid after the hernia has attained this size. Operation should be performed before severe incarceration, with consequent obstruction and traumatic lesions of the stomach, has occurred. The operative risk is increased by gastric retention and the technical difficulties are enhanced by fixation of the stomach to the diaphragm and to the hernial sac within the thorax. In cases in which the colon is involved in the hernia, early operation is necessary because of the danger of occurrence of intestinal obstruction.

In most cases of esophageal hiatus hernia, I prefer to perform temporary interruption of the phrenic nerve by crushing the nerve preliminary to abdominal repair of the hernia because permanent paralysis of the diaphragm is rarely necessary in this type of hernia. As a procedure preliminary to radical surgical treatment, interruption of the phrenic nerve is often of value in treatment of incarcerated and strangulated hernias because it prevents spasm of muscle and causes relaxation of the hernial ring.

Permanent interruption of the phrenic nerve may be a necessary procedure in the surgical treatment of partial thoracic stomach resulting from a congenitally short esophagus. I wish to emphasize, however, that permanent interruption of the phrenic nerve is rarely necessary and should never be done in cases of esophageal hiatus hernia until it is definitely ascertained that it is not advisable to re-establish the function of the diaphragm. It should be emphasized also that this procedure cannot replace the operative repair of the hernia. It is important to bear in mind that the atrophy of the diaphragmatic muscle which follows permanent interruption of the phrenic nerve may make it impossible to obtain a satisfactory result in the event of further radical repair of the hernia.

I prefer the abdominal approach in all cases of esophageal hiatus hernia for several reasons. In these hernias the herniated viscera are contained in a sac in the posterior mediastinum and do not enter the pleural cavity. The removal of the sac or the attachment of the sac to the stomach is one of the most important steps in the operative repair of these hernias. The attachment of the hernial sac to the stomach can be exposed only by the abdominal approach. The types of defective esophageal hiatus can be determined and hernias with a posteriorly defective muscle ring can be repaired with less risk of injury to the spleen, aorta, or caudate lobe of the liver, and the esophagus can be more easily visualized and fixed to the repaired hiatus from the abdominal side of the diaphragm. Hernias complicated by gastric erosion or ulcer and any associated conditions such as

rhage that results from the ulceration is so severe as to endanger life. Traumatic ulcers may be multiple, are usually relatively superficial and depend on the mechanical derangement of the herniated stomach for their presence. After repair of the hernia and replacement of the stomach into its normal position most of the traumatic ulcerations heal spontaneously In several instances the traumatic ulcer has become more deeply seated, simulating the usual type of peptic ulcer, and has not healed after repair of the hernia. In the few cases of this type that I have seen the symptoms have been of long standing or the patient's condition has been one of severe incarceration.

In other instances the patient may not be aware of any bleeding but may have severe secondary anemia resulting from occult hemorrhage into the stool. I should like to emphasize the importance of secondary anemia as one of the important clinical manifestations of this type of hernia. It was noted in 11 per cent of all cases in which I performed operation. Secondary anemia, however, was not present in all cases in which traumatic ulceration was present, as in 19 per cent of these cases ulceration was noted on esophagoscopic examination.

In cases in which surgical treatment of the hernia is considered, one of the most important groups is that in which the symptoms simulate angina pectoris, for there are often no definite findings on which the diagnosis of coronary disease can be established. It is to be remembered that although a patient has a definite esophageal hiatus hernia that could adequately explain the symptoms, the patient can also have coronary sclerosis without proved signs and, if this condition is present, it constitutes a marked hazard to surgical intervention for the hernia.

Patients who have esophageal hiatus hernia of which the predominating symptoms are those of esophageal obstruction, are of particular interest and require careful clinical study. The symptoms may be attributable to an entirely unassociated lesion of the lower part of the esophagus, such as cardiospasm, carcinoma, or diverticulum, or they may be the result of ulceration, or stricture of the esophagus caused by the hernia. This esophageal ulceration produced by hernia is attributable to the angulation and pressure of the hernial sac on the lower part of the esophagus or is caused by regurgitation of food or gastric secretion into the lower part of the esophagus The ulceration may be a small, localized lesion or it may involve the entire circumference of the lower part of the esophagus and later may contract and produce a stricture Because of the possibility of a lesion in the lower end of the esophagus, caused by or unassociated with the hernia, I believe esophagoscopic examination is advisable in all cases. Esophagoscopic examination is essential also in determining definitely the presence of a traumatic ulcer, as these lesions are rarely demonstrable by roentgenologic examination. In rare instances the colon may be the only hollow abdominal viscera involved in the hernia. In these cases the subjective symptoms are those of intestinal obstruction (Figs. 8 and 9).

Surgical Treatment

From the standpoint of management, hiatal hernias may be divided into three groups. In the first group the hernia is small, is recognized roentgenologically, often during the course of a general examination, and causes few or no clinical symptoms. No treatment is indicated in this group of cases. The second group

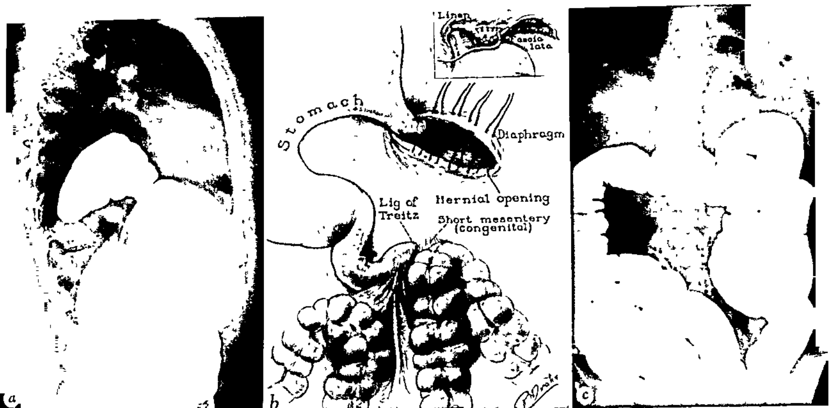


Fig 9.—The same case as is shown in Fig. 8. (*a*) Lateral view of the colon before operation which shows the large loop of colon herniated into the thoracic cavity. (*b*) Enlarged esophageal hiatus after the herniated portion of the intestine has been replaced into the abdomen. The congenitally short transverse mesocolon attached at the ligament of Treitz caused partial obstruction of the third portion of the duodenum. The dilated stomach was entirely below the diaphragm. The insert shows the repair and reconstruction of the enlarged esophageal hiatus around the lower portion of the esophagus with interrupted linen and continuous fascia lata. (*c*) Three weeks after repair of the hernia The entire colon is in normal position below the diaphragm



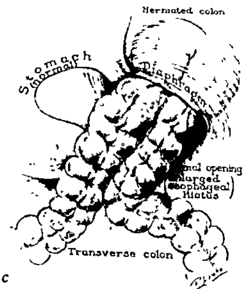


FIG 8.—Esophageal hiatus diaphragmatic hernia in a patient 16 years of age Herniation of a large loop of the transverse colon into the left portion of the thoracic cavity and partial obstruction of the colon have occurred, also partial obstruction of the duodenum due to a congenitally short transverse mesocolon with attachment close to the ligament of Treitz. (*a*) A large loop of transverse colon herniated through the esophageal hiatus into the left portion of the thoracic cavity obscuring the shadow of the heart (*b*) On admission, the stomach was moderately dilated but in normal position below the diaphragm and was not involved in the hernia (*c*) Operation revealed a congenital fixation of loop of the transverse colon which had herniated through an enlarged esophageal hiatus to the left of the esophagus, the stomach was in normal position below the diaphragm

abdomen is opened, the tube being directed into the obstructed portion of the stomach in order to empty the gastric contents before any attempt is made to reduce the herniated viscera, because of the danger of regurgitation and aspiration of gastric contents into the lungs. In some instances in large hernias, it may be difficult to withdraw the stomach from the hernial sac because of negative pressure in the sac. This can usually be reduced by placing a tube into the sac and permitting air to enter the hernial sac. This, however, is rarely necessary if the herniated portion of the stomach can be relieved of its contents of air or fluid. Before closure of the defective esophageal hiatus around the lower part of the esophagus is completed, it is important that a stomach tube of large caliber be

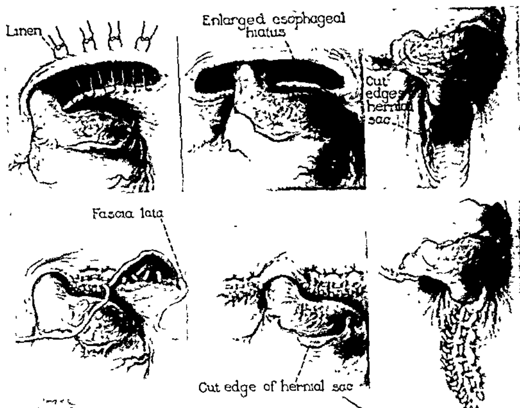


FIG 10—The commoner types of structurally deficient esophageal openings which permit herniation of the stomach into the posterior mediastinum and the method of repair of each type of opening with fascia lata and linen after removal of the hernial sac.

passed through the esophagus into the stomach, to aid in the reconstruction of the normal esophageal opening and to prevent constriction of the esophagus by a tight closure The loose areolar tissue or a small portion of the esophageal wall at the cardia is incorporated into the innermost margin of the closure by a suture of chromic catgut. In cases where there has been considerable elevation of the esophagus above the diaphragm, I suture the cardia of the stomach close to the esophagus to the undersurface of the diaphragm to aid in preventing the subsequent elevation of the esophagus and recurrence of the hernia due to contraction of the longitudinal muscles of the esophagus, which is the commonest cause of recurrences in this type of hernia.

pyloric obstruction or other abdominal lesions can be recognized and treated if necessary from the abdominal approach. Any injury to the stomach or the abdominal viscera which occurs during operation can be readily recognized and immediately repaired. I believe there is less risk of pleural complications when these hernias are repaired by the abdominal approach than when they are repaired by the thoracic approach. From a fundamental standpoint, I do not believe it advisable to traumatize the pleural cavity to approach these hernias, which are not in the pleural cavity but in the posterior mediastinum, when they can be satisfactorily approached from the abdomen.

An oblique incision is made in the left rectus muscle and peritoneum, extending to the xiphoid process. The technical difficulties of adequate exposure of the esophageal hiatus are often considerable because of fixation of the left lobe of the liver to the leaf of the diaphragm. The exposure of the hiatus is greatly facilitated by cutting the suspensory ligament and retracting the left lobe of the liver to the right. This can be accomplished, when the left lobe is small, by folding it on itself, and when it is large, by retracting it forward into the incision. The spleen is often adherent to the posterior part of the diaphragm and hernial opening but usually can be separated from these structures by blunt dissection. It is retracted posteriorly by a specially constructed retractor. In some instances the spleen may be drawn almost into the hiatus and may be so traumatized by separating it from its peritoneal attachments that its removal is advisable.

Hernias through the esophageal hiatus are true hernias and have a hernial sac consisting of abdominal peritoneum which is continuous with the serosa of the stomach. The attachment of the sac to the stomach must be severed and the sac must either be removed completely or permitted to retract into the posterior portion of the mediastinum I believe that this is one of the most important technical considerations in the surgical treatment of this type of hernia.

If the sac has been removed, the enlarged defective esophageal hiatus is repaired by overlapping the margins of the opening. In many instances it is necessary to elevate the diaphragm so as to reconstruct the hiatus at a higher position on the esophagus. This is an important procedure in those cases in which there is any shortening of the esophagus or marked elevation of the esophagus into the thoracic cavity (Fig. 10). Repair is usually made to the left of the esophagus but in some cases it is necessary to repair the opening partially both to the right and to the left of the esophagus. In some instances the defect of the esophageal hiatus is posterior, extending to the spinal column. This type requires the overlapping of the margins posterior to the esophagus. In such cases, the condition is often thought to be a herniation through the aortic opening but extending over the aorta there usually is an imperfectly developed fibrous band which is the margin of the defective esophageal hiatus The closure is usually made with living sutures of fascia lata, which are removed from the thigh The overlapped margins of the hernial opening are stabilized first with interrupted linen sutures. The fascia lata is then woven into the tissues by continuous suture and fixed in the tissues with interrupted linen sutures.

In many instances in which the stomach is incarcerated or obstructed, it is impossible to pass a stomach tube into the obstructed loculus of the stomach before operation. In these cases it is advisable to pass a stomach tube soon after the

the marked variation in the clinical symptoms and the frequency with which these symptoms simulate those of other organic diseases such as disease of the gallbladder or gastric or duodenal ulcer. In the series of 418 cases in which the patients were treated surgically, an average of more than three erroneous clinical diagnoses was made before the correct diagnosis was established. This also presents an important surgical consideration in that in approximately 10 per cent of these cases the patient had had a previous operation for a condition other than the hiatal hernia, the commonest of which was cholecystectomy, without relief of symptoms. The clinical symptoms recurred soon after these operative procedures and the patients were relieved only after repair of the hernia.

In the series of 381 cases in which radical repair of the hernia was performed, it was found necessary to do other operative procedures at the time of repair of the hernia in 19 cases. The additional operative procedures in these 19 cases were as follows: gastric resection for gastric ulcer, 4, gastric resection for carcinoma of the stomach, 2; closure of perforated gastric ulcer, 2, gastro-enterostomy for gastric ulcer, 1; gastro-enterostomy for duodenal ulcer with obstruction, 2; vagotomy for duodenal ulcer, 1, segmental resection of stomach for gastric leiomyoma, 1; splenectomy, 4; cholecystostomy for subacute cholecystitis with stone, 1; resection of esophagus for carcinoma of the lower esophagus, 1. Death occurred in 1 of the 19 cases: the patient having carcinoma of the lower esophagus died on the tenth postoperative day, from bronchopneumonia.

SUBCOSTOSTERNAL HERNIA THROUGH THE FORAMEN OF MORGAGNI (LARREY'S SPACE)

Herniation of abdominal viscera through regions of deficiency of muscle in the anterior portion of the diaphragm close to the sternum has received various names, such as "diaphragmatic hernia through the foramen of Morgagni, or through Larrey's fissure or space," and also "substernal," "retrosternal," "parasternal," or "anterior diaphragmatic hernia." Inasmuch as these hernias usually occur on either side of the anterior midline of the diaphragm, if an anatomic term is to be used, it would be preferable to designate them as "subcostosternal diaphragmatic hernias"

There is some difference of opinion as to whether these hernias should be classified as congenital or acquired hernias. It is impossible to explain their occurrence on a basis of faulty fusion or improper disposition of the embryonic mesodermic elements which go to form the diaphragm, as this anterior portion of the diaphragm is derived from the septum transversum only. But the consistency of the location of the hernial opening, the fairly constant relationship of the neck of the hernial sac to the round and falciform ligaments of the liver and the frequency with which the hernial sac protrudes into the right side of the thoracic cavity at the same point, that is, at the cardiophrenic angle, as well as the often associated nonrotation of the right portion of the colon, all strongly suggest a fundamental embryologic basis for these hernias

These hernias are essentially direct hernias through a congenital defect *in the* structure of the diaphragm or a faulty attachment of the diaphragm to the sternum and costal cartilages. They are usually unilateral with the opening close to the

The abdomen always should be thoroughly explored for the presence of any other lesion, particularly of the stomach or gallbladder. In some cases it may be necessary to operate on other associated lesions. I do not believe it advisable to carry out any additional surgical procedure at the time of repairing the hernia, unless it is imperative, but it is well to know whether or not the patient has gallstones or any other lesion in the upper part of the abdomen which might account for subsequent symptoms. It is often imperative, however, to perform other operative procedures at the time of repair of the hiatal hernia, and in many instances these are extensive operations such as resection of the stomach for carcinoma, gastric ulcer, or duodenal ulcer with obstruction. These additional operative procedures increase the risk of operation but they are only done when necessary for the recovery of the patient.

Inasmuch as the surgical treatment of this type of hernia is the repair of an abnormally large hiatus and not the complete closure of an abnormal opening, it is associated with a higher percentage of recurrence than other types of diaphragmatic hernia Recurrences seldom occur in the true para-esophageal type in which the esophagus has remained in its normal position and the hiatus is repaired up to the esophagus. When recurrences do occur it is usually in those types in which there is marked elevation of the esophagus associated with the herniation of the cardiac end of the stomach, and the chief technical difficulty is the fixation of the lower end of the stomach to the margins of the repaired esophageal hiatus.

Surgical Considerations and Results. My experience in the surgical treatment of the different types of esophageal hiatus hernias, consists of a series of 418 cases Of this series 381 had radical repair of the hernia. Of the 381 cases recurrence of the hernia developed in 11, in 5 of these cases the recurrence and symptoms were severe enough to require a second operation. In the remaining 6 cases, the recurrence involved only a small portion of the stomach and was associated with relatively mild symptoms, conservative measures such as dilatation of the esophagus and loss of weight were sufficient to relieve the symptoms In the 381 cases in which radical repair of the hernia was done, death occurred in 6, an operative mortality rate of 1 6 per cent

In the remaining 37 of the 418 cases of esophageal hiatus hernia which were treated surgically interruption of the phrenic nerve was the only surgical procedure As has been stated before, this procedure was performed in a number of different types of cases, such as cases in which a small hiatal hernia occurred, in reality an incompetent esophageal hiatus often associated with spasm of the lower part of the esophagus, the cardia, or the diaphragm, and cases in which radical operative repair was inadvisable because of other serious unassociated disease, because of poor general condition of elderly patients, or because of marked spasm or contraction of the diaphragmatic opening There was considerable variation in the results obtained in these different types of hernias Approximately 50 per cent of the patients obtained marked relief of symptoms. In 40 per cent of the remaining cases the patients were partially relieved and in 10 per cent they received essentially no relief of symptoms There were no operative deaths in this group of 37 cases.

As I have stated previously under the general considerations of the esophageal hiatus hernias, one of the most important clinical considerations of these cases is



FIG. 11.—Right subcostosternal (foramen of Morgagni) diaphragmatic hernia with herniation of the stomach, transverse colon, and omentum into the thoracic cavity of a woman 46 years of age. (*a*) On admission, note the diffuse density of the lower portion of the thoracic cavity. A previous diagnosis was a tumor of the thorax. (*b*) A large loop of colon herniated into the anterior right portion of the thoracic cavity. (*c*) Herniation of two-thirds of the stomach and also a portion of the colon into the right portion of the thoracic cavity.

attachments of the right costal cartilages to the sternum but they may be bilateral with the smaller opening on the left side. The constant presence of a peritoneal sac shows that the peritoneum had closed off the abdominal cavity from the pleural cavity before the actual herniation of the abdominal viscera occurred. The hernial sac of the peritoneum is at the right cardiophrenic angle anteriorly; as the hernia increases in size, the sac extends into the right side of the thoracic cavity. Subcostosternal diaphragmatic hernia, in my experience, is one of the two types of diaphragmatic hernia which has a hernial sac. The other type of diaphragmatic [illegible]

[illegible] congenital in origin but are rarely present at birth, and occur in most instances in later life because of increased abdominal pressure on a congenitally defective diaphragm.

The abdominal viscera usually involved in the hernia are the colon, omentum, ileocecal coil, and rarely the stomach.

The subjective symptoms associated with these hernias are often indefinite and depend on the type and amount of abdominal viscera involved in the hernia. There are essentially two types: (1) those in which the omentum is the only abdominal structure involved in the hernia; (2) those in which the colon or stomach is involved in the hernia. In the cases in which the omentum is the only structure involved in the hernia, the symptoms are those essentially related to the thoracic cavity, such as dyspnea, cough, and pain in the lower part of the thorax. In those cases in which the hollow viscera are involved in the hernia, the symptoms are those of partial obstruction of the viscera involved as well as abdominal and thoracic pain.

The cases in which omentum only is involved in the hernia present a much more difficult clinical problem in arriving at a definite diagnosis. The subjective symptoms are entirely thoracic as a result of mechanical interference with respiration and expansion of the lungs. These symptoms suggest a primary pulmonary lesion and direct the clinical investigation to roentgenologic study of the thorax. The roentgenologic findings of an increased density in the pulmonary field justify the clinical diagnosis of a primary intrathoracic lesion, which may be thought to be an intrathoracic tumor. This erroneous clinical diagnosis is particularly likely to be made if there are no subjective symptoms to suggest that an abdominal condition may be present and, even though the gastro-intestinal tract is examined roentgenologically, no lesion is demonstrated as no abdominal hollow viscera are involved in the hernia

The treatment of these hernias is surgical closure of the abnormal opening in the diaphragm after replacement of the abdominal viscera (Figs. 11 and 12) I prefer an abdominal approach through the upper part of the right rectus muscle because the opening in the diaphragm is accessible and the abdominal contents of the hernia are more safely and easily reduced from the abdominal than from the thoracic side of the diaphragm, as the true relationship of the herniated viscera to the hernial sac can be accurately determined.

The method of closure of the neck of the sac and of the defect in the structure of the muscle of the diaphragm depends on the size and character of the opening.

SURGICAL CONSIDERATIONS AND RESULTS

Of the 521 patients having diaphragmatic hernia on whom I have operated, 14 had subcostosternal diaphragmatic hernias (foramen of Morgagni). All 14 patients had radical repair of the hernia through an abdominal approach. In 2 cases, an esophageal hiatus hernia was repaired at the same time. In 1 of these latter cases, the subcostosternal hernia was bilateral with the pyloric end of the stomach extending into the right thoracic cavity and the transverse colon into the left thoracic cavity. This was a recurrent subcostosternal hernia, the patient having had two previous operations elsewhere for repair of the hernia, one through a thoracic approach and one through an abdominal approach. The esophageal hiatus hernia which also was present consisted of herniation of about a fifth of the cardiac end of the stomach through an enlarged esophageal hiatus.

Of the 14 patients having subcostosternal diaphragmatic hernias, 6 were males and 8 were females. The hernia contained colon and omentum in 6 cases, omentum only in 4, stomach, colon, and omentum in 3, and stomach and omentum in 1. All 14 patients have recovered from the operation. At the time of this writing there has not been a recurrence of the hernia.

One of the important surgical considerations in this type of hernia is the difficulty of establishing a definite diagnosis of the hernia when the omentum is the only structure involved in the hernia. In some instances the shadow in the thorax may be interpreted as that of an intrathoracic tumor. One of these patients had thoracoplasty previously, on the basis of a thoracic tumor. The condition was found to be a subcostosternal hernia which could not be reduced from the thoracic side. The patient was operated on later for repair of the hernia through an abdominal approach

CONGENITAL DIAPHRAGMATIC HERNIAS DUE TO MALFORMATION AND STRUCTURAL DEFICIENCIES OF THE DIAPHRAGM AND ESOPHAGUS

The commoner hernias of this type are (1) those which result from congenital absence of a posterior portion of the diaphragm, (2) the pleuroperitoneal hiatus hernias (foramen of Bochdalek), (3) those caused by the congenital absence of an anterior portion of the diaphragm (foramen of Morgagni), and (4) congenital short esophagus with partial thoracic stomach. The latter two types, those caused by congenital absence of the anterior portion of the diaphragm (foramen of Morgagni) and congenital short esophagus with partial thoracic stomach, have been discussed in the forepart of this chapter. The remaining two types of congenital diaphragmatic hernia due to structural deficiencies of the diaphragm which are those of the pleuroperitoneal hiatus (foramen of Bochdalek) and those due to the lack of formation of the posterior portion of the diaphragm, are essentially of the same type and may be considered together, the difference being that of degree of malformation of the diaphragm The relationship between these hernias and the formation of the diaphragm has been discussed under the heading Embryologic Aspects

These hernias may occur in either the left or right side of the diaphragm but are much commoner through the left than through the right hemidiaphragm. The

Small linear openings may be closed by overlapping the margins. Larger transverse openings extending beneath the sternum are best closed by suturing the anterior margin of the defect in the diaphragmatic muscle to the posterior sheath of the rectus muscle and to the anterior thoracic wall.

The most satisfactory material for closure of the opening is living suture of fascia lata removed from the thigh and stabilized in the tissues with silk. The round ligament of the liver can be incorporated in this closure to strengthen it as well as to re-establish its position on the anterior abdominal wall.

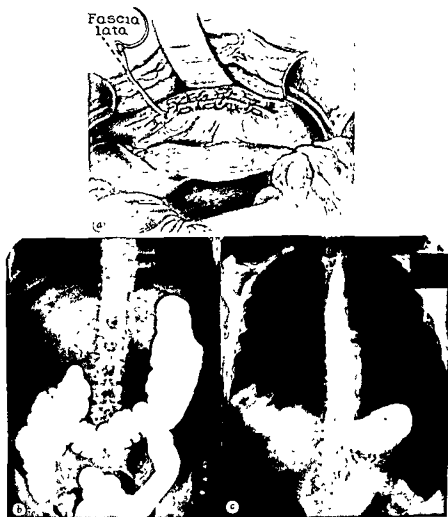


FIG 12—The same patient as shown in Fig 11 (*a*) At operation, overlapping closure of the hernial orifice with interrupted silk and continuous fascia lata sutures after removal of the colon from the thorax and cutting of the round ligament was performed by way of the abdominal approach (*b*) and (*c*) The entire colon and stomach are below the diaphragm

The closure of the large openings is facilitated by paralyzing the right side of the diaphragm by temporary interruption of the right phrenic nerve. This procedure, however, is not necessary in the closure of small openings. Preparation can be made to interrupt the phrenic nerve in the supraclavicular region after exploring the opening and determining whether or not interruption is necessary.

of the colon (appendix and cecum), the terminal part of the ileum, and all of the small intestine to the jejunum are involved in the hernia.

This type of hernia is said to be the commonest of the congenital types of hernia due to structural deficiencies. These hernias are present at birth. Many of the infants suffering from them die in the first few hours or days of life because of respiratory and cardiac embarrassment and before surgical intervention can be instituted. They should be operated on immediately if it can be established that the cardiac and respiratory embarrassment is due to the diaphragmatic hernia. In the treatment of those infants who are able to survive in spite of the altered intrathoracic pressure and thoracic visceral relationship, surgical intervention should be instituted as soon as possible because of the danger of intestinal obstruc-

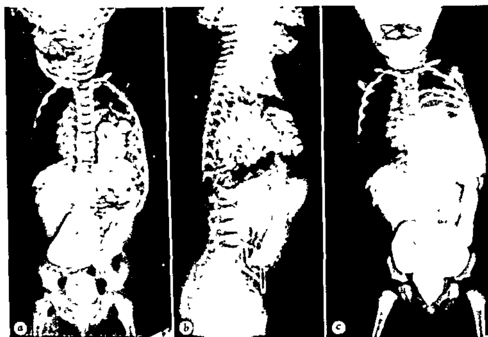


Fig. 13 – Congenital pleuroperitoneal hiatus diaphragmatic hernia in a baby girl 13 months of age. Herniation of the entire right portion of the colon, the transverse colon, and the small intestine into the left portion of the thoracic cavity. Roentgenograms were taken on admission of the patient (*a*) and (*b*) The small intestine herniated into the left portion of the thoracic cavity, the stomach is below the diaphragm (*c*) Herniation of the entire ascending and transverse colon into the left portion of the thoracic cavity

tion If they are able to maintain nourishment, it is well to delay operation for two to three months in order to permit some development of their accessory respiratory mechanism If operation is delayed for a long period, however, the abdominal viscera will have lost their right of residence in the abdomen in that the abdominal cavity will not have developed sufficiently to contain them and there will be a marked increase in intra-abdominal pressure when the viscera are replaced into the abdomen (Figs. 13 and 14).

In repair of the smaller hernias of this type, the opening can be closed without interruption of the phrenic nerve. On the other hand, in repair of the larger hernias interruption of the phrenic nerve is a necessary procedure. The opening is completely closed by overlapping the margins from 2 to 3 cm. If the patient is

kind of abdominal viscera involved in the hernia depends on whether or not the defect occurs in the right or left side of the diaphragm; the type of hernia and the severity of the symptoms often depend on the kind of viscera involved. Hernias of the right side may involve herniation of a portion of the dome of the liver only. These patients present few or no subjective symptoms. If the defect in the diaphragm extends beyond the abdominal attachments of the liver, the colon, the pyloric end of the stomach, and the small bowel may be involved in the hernia, and the patients may present symptoms of partial obstruction of these organs. When the defect occurs on the left side the more abdominal viscera are herniated into the left thoracic cavity, most commonly the colon, small bowel, stomach, spleen, and kidney, which produce more marked symptoms. The symptoms are often similar to those noted in association with the traumatic types of hernia Because of the occurrence of the hernia at birth, the respiratory and cardiac symptoms are usually severest, owing to the marked unilateral alteration in intrathoracic pressure and the occurrence of this derangement of intrathoracic pressure at a time at which the compensatory respiratory and cardiac reserve has not been developed to a sufficient degree to maintain function of these organs. Many infants born with these congenital defects die in the first few hours or days of life If the respiratory and cardiac mechanisms are able to compensate for the presence of these abdominal viscera in the thorax, however, these patients may live on to childhood or even to adult life without any great amount of disability or many symptoms, provided that intestinal or gastric obstruction does not develop. There is less likelihood of obstruction developing in these cases than in the cases of traumatic hernia because there are usually fewer adhesions between the abdominal viscera and the thoracic viscera in the former than in the latter. When the stomach is involved in these hernias, it usually becomes greatly dilated and these patients often have symptoms of partial gastric obstruction Intestinal obstruction may occur, owing to bands of adhesions between the omentum and loops of bowel or to inflammatory conditions of the bowel. Inasmuch as there is usually nonrotation of the right portion of the colon and the cecum, and the appendix is in the left thoracic cavity, appendicitis may develop and produce a serious hazard to life

In the surgical treatment of these hernias the approach may be either thoracic or abdominal, but I prefer the abdominal approach through an oblique left rectus incision

Pleuroperitoneal Hiatus Hernias

These hernias occur in the posterolateral portion of the diaphragm and are caused by failure of fusion of the pleuroperitoneal membrane and the septum transversum. The defect is usually triangular, with the apex toward the median portion of the diaphragm The defect usually extends to the thoracic wall but occasionally there is an imperfectly developed band of muscular tissue extending along the thoracic wall These hernias do not have a hernial sac and a direct communication exists between the abdominal and the thoracic cavity.

The commonest abdominal viscera involved in this type of hernia are the colon and the small bowel. There may or may not be herniation of the spleen and stomach. There is often a failure of rotation of the colon, and the entire right side



FIG 15—Congenital absence of the posterior portion of the diaphragm, with herniation of the entire stomach, transverse colon, small intestine, and spleen into the left portion of the thoracic cavity in a man 31 years of age. (*a*), (*b*), and (*c*) On admission of the patient. Herniation of the entire stomach into the posterior left portion of the thorax and of the colon into the anterior portion of the thorax. The left lung is collapsed

an infant, this closure is made with interrupted silk sutures. Before the opening is completely closed, the air is aspirated from the pleural cavity by inserting a catheter connected to a suction apparatus. At the time of withdrawal of the catheter the last suture is tied, completely closing the communication between the thorax and the abdomen.



FIG 14 —Same case as shown in Fig 13 (*a*) and (*b*) Five months after abdominal repair of the hernia, the stomach and colon are in normal position below the diaphragm. (*c*) The abdominal incision is completely healed No subjective symptoms are present.

One of the chief dangers associated with the repair of these hernias is marked alteration of intrathoracic or intra-abdominal pressure. It is important in these cases that the respiratory function be maintained by positive pressure during the operation and that at the completion of the operation negative pressure be secured and maintained in the thoracic cavity. A roentgenogram should be taken at the completion of the operation to see that there is no shift of the mediastinum due to the pneumothorax. I do not permit the patient to be moved from the operating table until I have seen the roentgenogram. If there is any shift of the mediastinum, more air is withdrawn to maintain the mediastinum in the midline.

CONGENITAL ABSENCE OF THE POSTERIOR PORTION OF THE DIAPHRAGM

This type of hernia results from failure of formation of that portion of the diaphragm which is derived from the pleuroperitoneal membrane. The defect is in the posterolateral portion of the diaphragm and usually extends from the eighth rib posteriorly and medially to the esophageal hiatus. These hernias usually do not have a sac but there may be an imperfectly developed enveloping membrane of peritoneum and omentum which simulates a sac These hernias may be considered as enlargements of the foregoing pleuroperitoneal type in that the essential difference is a much more extensive congenital defect in the formation of the diaphragm. There are more abdominal viscera involved in the hernia in that these hernias usually contain the stomach and spleen as well as portions of the large and small bowel (Figs 15 and 16) In some hernias of this type the kidney is above the level of the diaphragm in the thoracic cavity posterior to the pleura. I have noted the kidney in this position only when there is complete absence of the

a hernial sac. The herniated abdominal viscera were in direct contact with the thoracic viscera. One patient had a hernia through a structural deficiency of the muscle of the diaphragm (foramen of Bochdalek) in which the peritoneum and pleura had covered the opening. There was a hernial sac and the patient was 50 years of age.

The ages of the 24 patients with complete congenital deficiencies varied from five weeks to 33 years. Of the 25 patients 18 were males and 7 females. In 24 cases, the hernias were through the left half of the diaphragm and 1 was through the right half. The abdominal approach was used for 23 patients and the thoracic approach for 2.

The structures involved in the hernia varied with the size and type of structural defect. The commonest structures involved were the small bowel which was involved in 23 cases, and the colon which was involved in 22 cases. The cecum and appendix were involved in 9 cases, the stomach in 11 cases, the spleen in 13 cases, the kidney in 7 cases, the liver in 3 cases, and the pancreas in 1 case.

Nineteen patients underwent interruption of the phrenic nerve in conjunction with repair of the hernia. The spleen was removed from 3 patients and the appendix from 2 because of acute appendicitis. Thoracoplasty was done on 1 patient to narrow the diameter of the thorax and to facilitate the closure of a large defect in the diaphragm.

Seven patients died after operation. Eighteen patients recovered and have been completely relieved of symptoms.

One important consideration of these types of hernias is the frequent occurrence of other congenital anomalies in the abdomen such as nonrotation of the right portion of the colon with ascending colon, cecum, and appendix involved in the hernia. In 2 cases of this series, death was due to a ruptured appendix accompanied by abscess in the pleural cavity, empyema, and also peritonitis. One patient had an internal hernia with the small intestine involved in the congenital peritoneal membrane from the ileocecal coil to the jejunum, and also intestinal obstruction This patient died from thrombosis of the mesentery vessels The other 4 deaths in this series were due to pneumonia resulting from lack of expansion of the lung, which had been collapsed by the hernia, and cardiac failure.

TRAUMATIC DIAPHRAGMATIC HERNIA

Traumatic diaphragmatic hernia may be caused by direct or indirect injury or by inflammatory necrosis of the diaphragm In case of indirect injury of the diaphragm, the hernia may occur at any point, including points of embryologic fusion, but the commonest sites are the dome and the posterior half of the left part of the diaphragm. On the other hand, the hernia may occur in the right part of the diaphragm. It usually is the result of a severe, crushing injury. When the hernia occurs through the esophageal opening there is a sac, but when it occurs through the leaf of the diaphragm there usually is no sac. In case of direct injury of the diaphragm, the hernia may occur at any point and is usually the result of penetrating wounds, such as those inflicted by a gun or a knife.

Rupture of the diaphragm may be the result of inflammatory necrosis, which, in turn, has been caused by subdiaphragmatic abscess. Again, rupture may follow

diaphragm posteriorly. Presence of the kidney in the thoracic cavity can often be determined clinically by taking an intravenous pyelogram, and this procedure is often helpful in distinguishing between a pleuroperitoneal hiatus hernia and complete absence of the diaphragm posteriorly. In the pleuroperitoneal hiatus hernia a posterior segment of the diaphragm usually prevents the kidney from extending into the thoracic cavity back of the pleura.



Fig 16.—The same case as shown in Fig. 15 (*a*) and (*b*) Four months after abdominal repair of the hernia, showing the entire stomach and colon below the diaphragm in normal position and contour. The left lung is fully expanded

Not only do the surgical problems associated with these hernias involve all problems of the pleuroperitoneal hernias as far as altered intra-abdominal and intrathoracic pressure is concerned, but, in addition, there is the problem of closing this large gap with the diaphragmatic muscle that is present and of reconstructing the attachment of the diaphragmatic muscle to the thoracic wall. If the gap is not too great, this can be accomplished by complete, permanent interruption of the phrenic nerve If the defect is too large to permit the relaxed diaphragm to span this gap, it is necessary to shorten the diameter of the diaphragm by extrapleural rib resection

Surgical Considerations and Results

All types of diaphragmatic hernias were represented in the 524 cases of patients who underwent operation. Twenty-four patients had hernias due to complete congenital deficiency of the diaphragm, either of the pleuroperitoneal hiatus type (11 patients) or of the type caused by absence of the posterior portion of the diaphragm (13 patients). The hernias of these 24 patients were not contained in

necrosis caused by drainage tubes which have been introduced into empyematic cavities. In these cases the opening usually is situated in the posterior part of the diaphragm and there is no hernial sac.

Traumatic diaphragmatic hernias usually do not present the difficult diagnostic problems which are associated with esophageal hiatus hernia, for the occurrence of the injury leads the examiner to suspect the possible presence of a hernia. The symptoms associated with this type of hernia progress rapidly, are severe, and are attributable to the mechanical interference with the function of the heart and lungs. This is due to the fact that there is no hernial sac and the abdominal viscera are in direct contact with the thoracic viscera. The condition in these cases may be more properly termed "evisceration of the abdominal organs into the pleural cavity" rather than "true hernia." The most marked immediate symptoms are usually those of respiratory and circulatory embarrassment. These hernias are more frequent in adult life than in childhood and the compensatory cardiac and respiratory reserve usually carries the patient over the acute symptoms if the other associated injuries have not been too great. Later, severe hemorrhage from the gastro-intestinal tract may occur as a result of incarceration or strangulation of the hollow viscera. If the patient survives the acute condition, the later symptoms depend on the viscera involved. The symptoms may consist in obstinate constipation, the occurrence of large quantities of gas in the colon and attacks of partial or complete intestinal or gastric obstruction. The sudden onset of symptoms in cases of traumatic hernia usually is related directly to the injury and there is rarely a question as to the clinical diagnosis. Surgical treatment is demanded because of the danger of cardiac and respiratory failure or because of intestinal strangulation.

In those types of diaphragmatic hernia which result from inflammatory necrosis of the diaphragmatic muscle (Fig. 17), the symptoms are often somewhat obscure and in many instances they are unrecognized for a long period because the possibility of a hernia is not considered and the symptoms are often thought to be due to the primary illness. In some instances the hernia does not occur for many months after the patient has recovered from the primary illness.

Traumatic hernias demand immediate surgical treatment if there is any indication of an associated injury to the hollow viscera. This is particularly true in those cases in which the hernia is due to traumatic injury. In cases in which the hernia is caused by indirect injury, there is less likelihood of rupture of a hollow viscus and surgical treatment may be delayed until the acute symptoms caused by the primary injury have subsided. However, operation in these cases should be done as soon as possible because of the danger of the occurrence of intestinal obstruction. It is important that there should be no long interval of delay because the herniated abdominal viscera will lose their right of residence in the abdomen. When a large amount of abdominal viscera has remained in the thoracic cavity for a long period, the viscera become dilated because of the difficulty in performing their normal function, and the abdominal cavity, which has not contained them for a long period, becomes smaller. These factors tend to increase the hazard of operation as well as the risk of recurrence of the hernia because when these viscera are replaced into the abdomen they markedly increase the intra-abdominal pressure (Figs. 18 and 19).



Fig 17.—A woman aged 36 years had a left diaphragmatic hernia with herniation of a large segment of the stomach, spleen, and omentum through the dome of the left portion of the diaphragm due to inflammatory necrosis associated with subphrenic abscess secondary to a ruptured appendix 16 years previously. (*a*) and (*b*) On admission, herniation of a large segment of the greater curvature of the stomach through the central part of the dome of the left part of the diaphragm (*c*) Three weeks after abdominal repair of the hernia, showing the entire stomach in normal position below the diaphragm.



FIG. 19.—Same case as shown in Fig. 18 Three weeks after right transthoracic repair of the hernia. (*a*) The entire liver is below the diaphragm; pleuritic adhesions of the right base; stomach normal. (*b*) The entire colon is below the diaphragm. (*c*) Photograph taken on dismissal, showing the healed right posterolateral incision The patient has good function of his arm.



Fig 18 – Traumatic diaphragmatic hernia in a man 58 years of age, with herniation of the right lobe of the liver and loops of the transverse colon into the right portion of the thoracic cavity, as the result of an indirect injury in an automobile accident nine years before admission (*a*) Roentgenogram taken on admission reveals diffuse density in the right lower portion of the thorax, previously diagnosed as elevation of the diaphragm. (*b*) Evidence revealed a loop of colon in the right anterior part of the thorax, above and anterior to the liver. (*c*) On admission the shadow of the stomach revealed it to be below the diaphragm, and evidence is shown of diverticulum in the mid-esophagus.

believe this to be the most satisfactory type of closure in all these cases. In cases of traumatic hernia in which the laceration is confined to the dome of the diaphragmatic muscle, it usually is advisable to repair the opening by lapping the anterior margin over the posterior margin of the opening. When possible, it is advisable to overlap the margins of the opening from 2 to 3 cm. In those cases in which the laceration splits the muscle of the esophageal ring, great care should be taken in repairing the esophageal hiatus. In those cases in which the laceration extends to the margin of the thorax and in which the attachments of the diaphragm are torn from the thoracic wall, the repair is made not only by overlapping the laceration of the leaf of the diaphragm but by resuturing the diaphragmatic muscle to the thoracic wall. This can be accomplished by suturing the diaphragmatic muscle to the intercostal muscles. When possible, the diaphragmatic muscle should span two interspaces, being fixed to the intercostal muscles with fascia lata and stabilized with interrupted linen sutures (Figs. 20 and 21).

In a few instances, relaxation of the diaphragmatic muscle caused by interruption of the phrenic nerve will not be sufficient for repair of the defect. In these cases the diameter of the thorax must be narrowed by resecting the lower ribs by thoracoplasty. It is usually not necessary to resect more than a few inches of the eighth, ninth, and tenth ribs at the angles.

Before the abdomen is closed, the herniated viscera should be thoroughly explored, to be certain that there has been no injury to a viscus and that there are no bands of adhesions which will interfere with the function of the abdominal viscera In cases in which there has been considerable obstruction of the large bowel, it may be necessary to perform appendicostomy or colostomy at the time of operation.

Surgical Considerations and Results

Of the 524 patients having diaphragmatic hernia who underwent operation, 7 had hernias due to inflammatory necrosis resulting from subphrenic abscess or drainage of empyema and 60 had hernias due to various types of injury. The hernias in 6 of these 60 cases were due to traumatic injury to the diaphragm, in 5 to gunshot wounds, and in 1 to a stab wound. Fifty-four hernias were due to indirect injury to the diaphragm; the commonest cause of injury was automobile accidents which caused the hernia in 42 cases. The remaining 12 of these 54 hernias were due to indirect injury caused by various types of crushing injuries such as landslides, falls from ladders, or being thrown from a horse.

Of the total traumatic cases, 55 patients were males and 12 were females. The hernia occurred through the left portion of the diaphragm in 65 cases and through the right portion in 2 cases

The method of surgical approach for radical repair of the hernia was through the abdomen in 64 cases, through the thorax in 2 cases, and through a combined thoracic and abdominal approach in 1 case Interruption of the phrenic nerve was done in 62 cases in conjunction with the repair. A thoracoplasty was performed in 3 cases to narrow the diameter of the thorax in order to permit closure of the large defect in the diaphragm In 2 cases there was an associated intestinal obstruction, in 1 of which appendicostomy was done and in 1 an enterostomy.

The surgical approach to these hernias may be through the thorax or through the abdomen. For all hernias through the right side of the diaphragm, I prefer the thoracic approach because the large right lobe of the liver interferes with the

exp

In

and its reduction is more safely accomplished through the thoracic approach than through the abdominal approach because there is less danger of hemorrhage from injury to the liver.

In all traumatic hernias through the left side of the diaphragm, I prefer the abdominal approach through an oblique left rectus incision. The herniated viscera are usually adherent to both the abdominal and the thoracic side of the diaphragm



Fig. 20 —A boy aged 14 years, with traumatic (auto accident) diaphragmatic hernia on the left side with herniation of the entire stomach, the small intestine, the transverse colon, and the left lobe of the liver into the left portion of the thoracic cavity. The lower part of the left lung is collapsed and the heart is displaced to the right. (*a*) Thorax on admission, showing hollow viscera in the left lower portion of the thorax which has resulted in collapsing the lung and displacing the heart to the right. (*b*) and (*c*) The entire stomach and small intestine almost fill the posterior portion of the thoracic cavity on the left. The stomach extends to the second rib

and to the structures within the thorax. The adhesions to the margins of the opening and to the undersurface of the diaphragm are often marked and should be separated first. The adhesions to the structures within the thoracic cavity are separated from below upward by approaching them through the hernial opening. By the abdominal approach this can be accomplished with little danger of injury to the abdominal or thoracic viscera, because the definite relationship of the herniated structures can be established

In cases in which there has been considerable loss of structure or in which the muscle has been torn from its attachment to the thoracic wall, the defect in the diaphragm should be repaired by fascia lata stabilized with linen sutures. I

One patient required splenectomy because of previous trauma and fixation of the spleen to the hernial opening.

The abdominal viscera involved in the hernia varied, depending on the location and size of the opening. The stomach was incorporated in the hernia in 66 cases, colon in 59 cases, small bowel in 38, spleen in 30, liver in 20, and kidney in 2.

The defect in the diaphragm of all 67 patients was completely closed with fascia lata and interrupted silk.

There were 5 operative deaths or an operative mortality rate of 7.4 per cent. One death was due to rupture of the stomach which was present at the time of the operation, 1 to intestinal obstruction and 3 to pneumonia. Sixty-two of the 67 patients operated on recovered from the operation and have had no recurrence of hernia.

POSTOPERATIVE MANAGEMENT

Postoperative considerations of diaphragmatic hernia begin in the operating room at the completion of the operation. The most important period of postoperative care is from the time of completion of the operation until the patient has fully recovered from the anesthesia with re-establishment of normal reflexes and functions

At the completion of the operation roentgenograms of the thorax are taken and read before the patient is removed from the operating room. It is extremely important to determine the presence or absence of any abnormal condition or position of the intrathoracic viscera. If some abnormal condition is present, it should be corrected before the patient leaves the operating table.

Two of the more important immediate postoperative conditions which imperil recovery of the patient after operation are (1) displacement of the mediastinum and (2) pulmonary congestion. If these conditions are present they markedly interfere with cardiac and respiratory function and this interference may result fatally if not immediately relieved. Mediastinal displacement is due to pneumothorax and must be immediately relieved by withdrawal of sufficient air to produce negative intrathoracic pressure and bring the mediastinum to the midline. Pulmonary congestion is due to retention or aspiration of secretions and is best relieved by immediate bronchoscopic aspiration of the lung. Patients who require immediate postoperative treatment should have a second roentgenogram taken and read after treatment has been instituted to be certain that the condition is corrected before the patient is taken from the operating table.

Most patients are given a blood transfusion either during or immediately after the operation. The blood of every patient is grouped for transfusion before the operation. If the systolic blood pressure decreases to 90 mm of mercury or less,

---

FIG 21 —Same case as shown in Fig 20 (*a*) At operation [illegible] approach by left rectus [illegible] the left portion of the [illegible] the lower left shows the esophageal hiatus The lower insert shows [illegible] diaphragm, not involving the [illegible] overlapping closure of the hernial opening with interrupted silk and continuous fascia lata (*b*) and (*c*) On dismissal three weeks after abdominal repair of the hernia the entire stomach and colon are in normal position below the diaphragm, the heart is in normal position, and the left lung is fully expanded.



Caption on opposite page.

TABLE II

SURGICAL PROCEDURES AND OPERATIVE RESULTS: 524 CASES

Radical repair of defect in diaphragm:		
Approach: abdominal: 483, thoracic: 3; combined: 1		487
Preliminary interruption of phrenic nerve	380	
Preliminary extrapleural thoracoplasty	4	
Operations in conjunction with repair of hernia:		
Gastric resection for gastric ulcer (4); carcinoma (2)	6	
Closure perforated gastric erosion (2) (total erosion 39)	2	
Gastro-enterostomy for gastric ulcer (1); duodenal ulcer (2) ..	3	
Vagotomy for duodenal ulcer	1	
Removal of gastric leiomyoma	1	
Splenectomy for tuberculosis (2), injury (9)	11	
Cholecystostomy for subacute ruptured gallbladder	1	
Appendicostomy for obstruction	1	
Appendectomy for appendicitis	5	
Interruption of left phrenic nerve (hiatal hernia)		
Palliative, 9, therapeutic, 28		37
Total patients operated		524

Recurrence of hernia in all types operated:

[illegible] geal hiatus (11)

[illegible] oms (6)

[illegible] (5)

Repair of recurrent hernias (5)

Operative deaths, 18 or 3.4 per cent (basis of 524 patients operated on)

the patient should receive a transfusion of blood. I believe it is very important to maintain blood pressure at a fairly constant level and not permit it to drop more than 20 mm. of mercury below the normal preoperative reading. I prefer the use of blood transfusions to the use of other intravenous solutions or of drugs to maintain the blood pressure. Blood transfusions are also advisable in all cases in which the hernia is associated with loss of blood producing a secondary anemia

When the patient has been removed to the hospital bed, which has been made warm by hot water bottles, external heat is applied by the use of additional hot water bottles Fifty-eight to 60 per cent oxygen is administered in an oxygen tent until the patient has fully recovered consciousness and its administration is continued thereafter as indicated. After the patient has fully regained consciousness, the oxygen may be administered with a nasal mask

Care should be exercised in the selection and amount of sedation used. This is particularly important if there is any respiratory embarrassment. Sedation should be limited so as not to decrease the respiratory function. I prefer using codeine supplemented by a small amount of morphine to relieve severe pain. In all cases in which dilatation of the stomach is present at the time of operation, intermittent or continuous gastric lavage is employed to keep the stomach empty for the first three to five days after the operation.

All patients are given glucose and physiologic salt solution intravenously for three to five days until they are able to take sufficient quantities of fluids by mouth Administration of fluids by mouth is usually started within 48 hours after operation In cases in which there has been herniation into the thoracic cavity of a large portion of the abdominal viscera over a long period, the replacement of these viscera in the abdomen causes a marked increase of the intra-abdominal pressure, which may lead to partial or complete obstruction In cases of partial obstruction, the condition may be relieved by conservative measures, but in cases of complete obstruction, it may be necessary to perform enterostomy in order to reduce the intra-abdominal pressure and to relieve the obstruction.

In all cases in which the herniated viscera are removed from the pleural cavity, and in some cases in which the herniated viscera are removed from the posterior portion of the mediastinum, as would be the case of herniation through the esophageal hiatus, traumatic effusion occurs in the pleural cavity. The treatment of this effusion depends on the amount of respiratory embarrassment associated with it. In most instances the effusion is slight, it will gradually become absorbed so that special treatment will not be required. In cases in which the effusion progresses to produce respiratory embarrassment, pleurocentesis, performed one or more times, is required In some cases empyema may develop, requiring intercostal drainage, and possibly rib resection later In my experience empyema has rarely occurred in cases in which the hernia was repaired by the abdominal approach.

In some cases atelectasis may be caused by the lodgment of mucus in a bronchus. In most such cases the condition will respond to conservative treatment. It may sometimes be necessary to remove the mucus by bronchoscopic aspiration.

Table II is a brief summary of the surgical procedures used in the 524 cases of various types of diaphragmatic hernia in which operation was performed.

TABLE II

SURGICAL PROCEDURES AND OPERATIVE RESULTS 524 CASES

Radical repair of defect in diaphragm:		
Approach: abdominal, 483, thoracic, 3, combined, 1		487
Preliminary interruption of phrenic nerve	350	
Preliminary extrapleural thoracoplasty	1	

Operations in conjunction with repair of hernia

4), carcinoma (2)	6	
(2) (total erosion 39)	2	
(1), duodenal ulcer (2)	3	
Vagotomy for duodenal ulcer	1	
Removal of gastric leiomyoma	1	
Splenectomy for tuberculosis (2), injury (9)	11	
Cholecystostomy for subacute ruptured gallbladder	1	
Appendicostomy for obstruction	1	
Appendectomy for appendicitis	5	
Interruption of left phrenic nerve (hiatal hernia)		
Palliative, 9, therapeutic, 28		37
Total patients operated		524

Recurrence of hernia in all types operated:

Traumatic hernia (0), Congenital defect (1), Esophageal hiatus (11)

12)

e of symptoms (6)

symptoms (5)

Repair of recurrent hernias (5)

Operative deaths, 18 or 3.4 per cent (basis of 524 patients operated on)

Diagnosis and Treatment of the Infertile Male

FRED A. SIMMONS, M.D.

During the last half century, progress in the investigation of the infertile couple has been made with leaps and bounds as more and more attention has been paid to the husband. As long ago as 1904 W. G. Haggart said, "The woman should not bear the reproach until a microscopic examination of the partner has been made to determine the absence or presence of living healthy spermatozoa." Lay people and the medical profession, however, were slow to accept this sage advice, and even ignored the carefully emphasized recommendations of Dr. Samuel Meaker, in the authoritative text, *Human Sterility*, who said, "Testicles must produce normal spermatozoa," and advocated that, "(1) when one semen proves defective, final conclusions should be withheld until others have been examined, (2) No seminal specimen, however, satisfactory, eliminates the need for complete investigation of the male, or for postcoital examination of the female."

It must be emphasized that even today many physicians fail to comprehend the importance of investigating the individual who produces spermatozoa, as well as the spermatozoa themselves. Almost daily, in any large community or hospital, so-called sterile wives are being subjected to surgical procedures without a complete investigation of the male partner. If nothing further is accomplished by this presentation than to convince the reader that the husband should have the following carefully carried out investigations, much will have been added to the management of the infertile couple seeking relief from their plight.

Let us turn our attention at once to the steps indicated when a couple complains of infertility. Our problem here concerns only the husband. It is well to carry out an examination of the husband, even though the wife's status has not been completely evaluated. It is often worth while to complete the female diagnostic survey and therapy simultaneously with the male program. The male should have a complete history and physical examination, general laboratory examinations, including blood Wassermann, complete blood count, sedimentation rate, urinalysis, examination of the prostatic secretion, basal metabolic rate, and complete semen examination, including the recording of the volume, the percentage of motility, the number of sperm per cubic centimeter, and the morphology of the spermatozoa themselves. Table I includes the minimal diagnostic procedures which should be carried out on all cases.

Depending on the findings from these preliminary diagnostic procedures, subsequent investigation of the male may require a testicular biopsy, urinary assay for 17-ketosteroids and follicle-stimulating hormones, postcoital examination of the cervical mucus of the wife, at the proper time of the cycle, and therapeutic trials

with different drugs. A common misconception on the part of the medical profession is the idea that the generous use of various endocrine preparations parenterally or orally will relieve oligospermia. As will be emphasized later, there are few cases in which hormonal therapy, with the exception of thyroid orally, is routinely indicated in infertility.

TABLE I

ROUTINE MINIMAL DIAGNOSTIC PROCEDURES FOR HUSBAND

(1) Complete history and complete physical examination
(2) General laboratory examinations
  Blood Wassermann
  Complete blood count (with sedimentation rate if there is a high white blood count)
  Urinalysis
  Prostatic secretion, fluid specimen, and stained smear
(3) Basal metabolic rate
(4) Semen examination
  Volume
  Motility
  Number of spermia per cubic centimeter
  Type and ration of abnormal spermia
  (From *Urol. & Cutan Rev*, 47·558-570, 1942)

As an indication of the frequency of the problem, John MacLeod of Cornell University reports that of 1,500 semen analyses carried out in sterile marriages, only 40 per cent were completely satisfactory, while the writer has reported 536 cases, carried out in exactly the same type of study as Dr. MacLeod's, with only 40.4 per cent satisfactory specimens. The instance of complete azoospermia was 13.2 per cent in the author's series, and slightly over 10 per cent in MacLeod's cases. During the war years, in my office, of 79 men, physically fit armed forces personnel, 10 per cent had azoospermia and 38 per cent had specimens below the lowest limit of normal. Contrary to the general medical literature, of 71 cases of azoospermia, only one case was due to mumps and only 18 were due to gonorrhea, leaving over 50 per cent due to some failure of spermatogenic development. Detailed study of these cases is definitely warranted early in an effort to correct such deficiencies.

Because a practitioner has a degree in medicine it does not mean that he is equipped to study or treat the infertile couple; nor does a man competent in the field of endocrinology, or urology, or surgery, or gynecology and obstetrics necessarily know the minimal adequate investigation required in the study of infertility. Often, the distressed couple does not know to whom to turn. Therefore, it is essential for all physicians to keep themselves abreast of the proper handling of this common chief complaint. It is estimated that there were, a decade ago, 3,500,000 involuntary sterile marriages in the United States, and of these, 2,100,000 husbands may be presumed to be infertile.

It is trite to state that these couples offer a fertile field for treatment at the hands of the medical profession, but such is the case. Is it not, therefore, the duty of the profession to acquaint itself with the standards required to make a diagnosis, and also to treat such a volume of potential material? At the risk of offending some and antagonizing others, it must be emphatically proclaimed that the family doc-

tor and many eminent specialists need to admit their inadequacies in this type of study, and to acquaint themselves with the proper places to send these patients, where trained personnel can reward the couple's somewhat substantial financial outlay with at least the 25 to 40 per cent chance of successful pregnancy, on which even the best of clinics do not seem to improve year by year.

Far too often, the fault lies with the first doctor who innocently assures the parents that *they need have no concern* because a 'teen-age daughter does not mature or menstruate, or because a young boy does not seem to have both testes in the scrotum. Obesity in young males is frequently misdiagnosed as Frolich's *syndrome which is actually quite rare.*

It is not known how often school and college physicians and others prescribe for and treat young males with male sex hormone (testosterone), despite the report by Heckel, over a decade ago, *that the administration of testosterone by injection* or by mouth decreases spermatogenesis as long as it is given. The indiscriminate use of injections in too small or too large doses may cause irreparable damage to the young man's sensitive generative apparatus.

To those who turn to this chapter for their introduction to the problem of male infertility, the writer refers them at once to primers with which their patients may well be familiar before they come to the doctor. If you read E. C. Hamblen's *Facts For Childless Couples*, or A. I. Weisman's *You Too Can Have a Baby*, and can carry out fairly and satisfactorily the procedures recommended for husbands, then proceed with alacrity to the solution of your patient's plight. But if these tests and treatment cannot be carried out properly because of inexperience, it is your duty to refer the patient at once to the appropriate doctor or clinic. Occasionally religious tenets, moral scruples, or just plain prejudices sway a doctor's judgment in advising the patient. Lay people, particularly the infertile couple, will admire a man who frankly says he does not know, and sends them on to a higher counsel.

Minimal diagnostic procedures on the male are much less costly and dangerous than those on his wife, and anyone can learn to take and interpret the history properly, but it takes time (from 30 to 90 minutes). As will be *described below*, a complete physical examination includes a search for any stigma of infertility not generally considered important in a routine examination. This can be learned. Such a physical examination should take at least 20 to 40 *minutes.*

Semen analysis can also be learned, but not from a book. Anyone who today collects a condom specimen or does not require a definite period of abstinence before collection, is guilty of outmoded *practices or gross injustice* to the male. Cases are reported where the male is declared sterile after the doctor has done prostatic massage and found no sperm in the expressed secretion when it is examined microscopically. In well over 2,000 *prostatic massages*, in fertile men leading a normally active sex life, live sperm or any sperm was found in less than 1 per cent, in the digitally expressed secretion. It must not be overlooked that the finding of no sperm in the properly collected *bottle* specimen does not mean a man is sterile. There are cases where the man ejaculates none into the bottle, but sperm will be found in the cervix of the wife of the same man after normal coitus. Here, too, the male must not be *condemned if* spermatozoa found in the cervix are not motile, or even present, for Pommerenke has shown us that the cervical

with different drugs. A common misconception on the part of the medical profession is the idea that the generous use of various endocrine preparations parenterally or orally will relieve oligospermia. As will be emphasized later, there are few cases in which hormonal therapy, with the exception of thyroid orally, is routinely indicated in infertility.

TABLE I

ROUTINE MINIMAL DIAGNOSTIC PROCEDURES FOR HUSBAND

(1) Complete history and complete physical examination
(2) General laboratory examinations
  Blood Wassermann
  Complete blood count (with sedimentation rate if there is a high white blood count)
  Urinalysis
  Prostatic secretion, fluid specimen, and stained smear
(3) Basal metabolic rate
(4) Semen examination
  Volume
  Motility
  Number of spermia per cubic centimeter
  Type and ration of abnormal spermia
  (From *Urol & Cutan Rev*, 47 558-570, 1942.)

As an indication of the frequency of the problem, John MacLeod of Cornell University reports that of 1,500 semen analyses carried out in sterile marriages, only 40 per cent were completely satisfactory, while the writer has reported 536 cases, carried out in exactly the same type of study as Dr. MacLeod's, with only 40.4 per cent satisfactory specimens. The instance of complete azoospermia was 13.2 per cent in the author's series, and slightly over 10 per cent in MacLeod's cases. During the war years, in my office, of 79 men, physically fit armed forces personnel, 10 per cent had azoospermia and 38 per cent had specimens below the lowest limit of normal. Contrary to the general medical literature, of 71 cases of azoospermia, only one case was due to mumps and only 18 were due to gonorrhea, leaving over 50 per cent due to some failure of spermatogenic development. Detailed study of these cases is definitely warranted early in an effort to correct such deficiencies.

Because a practitioner has a degree in medicine it does not mean that he is equipped to study or treat the infertile couple; nor does a man competent in the field of endocrinology, or urology, or surgery, or gynecology and obstetrics necessarily know the minimal adequate investigation required in the study of infertility Often, the distressed couple does not know to whom to turn. Therefore, it is essential for all physicians to keep themselves abreast of the proper handling of this common chief complaint. It is estimated that there were, a decade ago, 3,500,000 involuntary sterile marriages in the United States, and of these, 2,100,000 husbands may be presumed to be infertile.

It is trite to state that these couples offer a fertile field for treatment at the hands of the medical profession, but such is the case. Is it not, therefore, the duty of the profession to acquaint itself with the standards required to make a diagnosis, and also to treat such a volume of potential material? At the risk of offending some and antagonizing others, it must be emphatically proclaimed that the family doc-

... tions are ... 16 hours after intercourse the examiner cannot find any spermatozoa.* Authorities throughout the country have been questioned on this difficult finding, and the explanation is still obscure. This is one of the few circumstances in the investigation and treatment of the sterile couple which might indicate an attempt at artificial insemination of the cervical mucus. This technic can be learned from any standard text on sterility, such as those by Siegler or Meaker or the publications of John Rock.

TAKING THE COMPLETE HISTORY

After recording the patient's name, address, age, duration of marriage, wife's age, and present occupation, investigation into previous occupations is pertinent (see Table II).

Occupation

Occupations which are recognized as being fraught with the possibility of producing ultimate male sterility are those of lead workers, x-ray technicians, those in which workers are exposed to the extremes of heat and cold, such as bakers and butchers, stokers, professional athletes, coaches, and those occupations having to do with electronics, electricity, radiation, radar, welding, cable-splicing, etc. Overwork may be a factor, especially in those striving for additional education, as demonstrated by a college student who holds one or two extracurricular jobs such as night work in a postal department or manual labor, in addition to classes during the day. Malnutrition is also a factor in graduate students particularly.

Hazardous occupations are too numerous to elaborate further here, but it must be understood that each case is to be evaluated independently, and the occupational factors weighed thoroughly. A minister, teacher, social worker, or office worker may have had undue exposure to the deleterious effects of heavy metals, poisons, fumes, or toxic substances during the war, when he worked in a shipyard or factory. There is at present, however, no indication that men who were prisoners of war, or subject to malnutrition during the war, have had their procreative powers affected irretrievably. The South Pacific theory regarding tropical heat and malnutrition, which is gaining impetus in various parts of the country, is also disproved by a complete study of the majority of cases.

A typical example of a combination of circumstances which inhibit male fertility is the case of a bus driver who was 35 pounds overweight, had a metabolism of −32 per cent, smoked more than a pack of cigarettes a day, and worked an eight-hour shift, sitting on a rubber-cushioned seat, with the heat and fumes of the motor arising through the front of the bus. He had no exercise at all, and in addition, wore "skin-tight" underwear, that is, shorts of the suspensory type, which maintain the testes close to the body, and affect the temperature of the scrotal content adversely. Correction of these factors improved his sperm count from less than 10,000,000 to 57,000,000 in five months, with subsequent prompt conception.

* A therapeutic trial with estrogenic substances, as suggested by Douglas, may produce results (*Proc. Int Congress Obst. & Gynec*, Dublin, 1947.)

mucus may be receptive and life-prolonging to normal spermatozoa for only a few hours of the entire menstrual cycle.

Again, anyone can learn to do the postcoital examination of the cervical mucus for the presence or absence of spermatozoa, but still the technic and the interpretation of this test are currently two of the most disputed points in almost every conference on human infertility.

POSTCOITAL EXAMINATION OF THE CERVICAL MUCUS FOR THE PRESENCE OF SPERMATOZOA

The Huhner test, or the Sims-Huhner test, for the demonstration of living spermatozoa in the cervical mucus at the proper time of the menstrual cycle is the most valuable adjunct to the investigation of the male and should be carried out by the physician who is examining the wife. The information should be transmitted to the doctor investigating the male. To be sure, it is probably preferable for one doctor to do the examinations on both the husband and the wife. Perhaps the urologist investigating the male might have the privilege of requesting that the wife report to his office for the investigation for the presence of spermatozoa in the cervix, with the permission of the referring physician. In this way, more stained smears can be done on the sperm found in the cervical mucus.

We have found that in over 20 cases, without exception the number of normal forms of stained spermatozoa in the cervical mucus exceeds the percentage of normal forms found in the bottle specimen (Simmons). This obviously implies that if cervical insemination takes place at all, the healthy normal sperm survive and the abnormal and diseased forms disappear. As has been indicated, it is not proper to condemn a male who has too few sperm in either the cervical mucus or the bottle *unless both tests are carried out more than once. The optimal time for doing* the postcoital cervical examination is during the wife's period of ovulation, which is normally around the 14th day of the menstrual cycle. This test can be carried out usually anywhere from the 11th to the 14th day However, care must be used in interpreting tests made after ovulation has occurred, for Pommerenke and others have demonstrated that the cervical mucus has a sudden hostility to sperm *invasion within 24 hours or longer after ovulation as depicted by basal body* temperature curves.

The technic is simple and consists mainly of exposing the cervix with a bivalve speculum, wiping the excess mucus from the cervix with cotton, and taking a bacteriology lo [illegible]
cervical canal [illegible]
the presence of [illegible]
considerable argument as to what is normal, and we have chosen to consider as normal a cervical mucus that reveals 25 to 50 actively motile spermatozoa per high powered field One sperm living in the cervix indicates that cervical insemination does occur, but does not imply that the insemination is that of a normally fertile individual. A repeat postcoital test should be made if no sperm are found under various circumstances, including the administration of the Ringer-Locke solution as a precoital douche during the fertile period. We are still at a loss as to the explanation for the failure to find living spermatozoa in the cervical mucus in

Exposure to venereal disease can be politely and expeditiously introduced at this point. A good technic is to say: "Did you have intercourse before marriage?" If the answer is "No," we are compelled to assume that the individual has not been exposed to venereal disease before marriage. If the answer is "Yes," one then inquires as to how old the individual was at the time of the first contact, whether protection was or was not used, and whether or not there is a history of venereal disease. If the individual has had venereal disease, we should know what kind of treatment he had, how long it was given, and whether any adequate assay was made at the conclusion as to his subsequent fertility. If there was involvement of the testes or epididymis, subsequent examination should reveal disease of the scrotal content It is fair to say that an individual with a known history of gonorrhea [illegible] epididymal involvement, and who has no sperm is sterile, owi[illegible]. It is also true [illegible] years after the disease, all could immediately be offered epididymovasostomy because all 25 showed normal spermatogenesis in the testes and live sperm in the epididymis.

The following systems require routine questioning with the appropriate elaboration of investigation as indicated by the individual case:

Cardiorespiratory Disease. Is there any pain in the chest, cough, or difficulty in breathing? These items need to be elaborated on if positive responses are elicited.

Gastro-intestinal Symptoms. Is the appetite good? Bowels regular? Any bleeding? Here can be recorded the weight and height, with particular attention to marked changes in the weight in the prepuberal or puberal era, or after marriage. If there are marked changes in weight, it should be investigated thoroughly, as, of course, obesity is a known factor in infertility.

A patient may have marked secondary anemia from chronic blood loss from the gastro-intestinal tract. Fluctuations in weight may reflect the general health pattern, or some specific endocrine or nervous upset.

Liver and Vitamin B Therapy. As the pattern of the patient's history and later physical examination indicate the possibility of liver damage, liver failure, or disorder of the digestive function, reference should be made to details in the history suggesting the advisability of special tests for the investigation of the liver. Biskind and Biskind introduced the idea that there may be some disorder of the liver-gonadal systems on the basis of vitamin B inadequacy. Recently they also intimated that vitamin E may be a factor.

With the return of the large number of our troops who had been exposed to infectious hepatitis, this problem presents itself en masse. There is a distinct possibility that a damaged liver may not metabolize estrogens and androgens in their proper ratio. Locally, in New England, those individuals coming to our attention who have had a history of infectious hepatitis have demonstrated their fertility since their return from the war by becoming parents. Thus far none of these men has been found to be infertile, but this does not rule out the necessity for investigating the status of the liver. The subject is still in such a state of flux that it is essential to call in the assistance of the internist, particularly one interested in liver diseases, to do the investigative work. There is a tremendous field for investigation in this aspect of male infertility.

Family History

Details should be elicited regarding the father and mother, living or dead, age of death, cause of death. It is not unwise to record the occupation of the patient's father at the time the patient was conceived or thereabout. The number of sisters and brothers should be recorded, and whether the patient is the first, third, or last child, and the number of years between him and the preceding child. The ages of the siblings are important and whether or not they are married and have reproduced. Patients often state that, since they come from a large family of perhaps 6 or 8 siblings, it is logical to assume that they are fertile. When it is pointed out that one out of 6 marriages is involuntarily sterile, it is logical that 1 out of 6 siblings may be sterile.

A reproductive history of brothers or sisters is valuable to record, as well as any family history of twins. If the patient himself is a twin, the status of the other twin should be investigated. It has been reported that in a set of twins one will be able to reproduce and another may not. It must be established whether there is any family history of tuberculosis, diabetes, heart disease, endocrine disease, malignancy, infertility, or frequent miscarriages.

Past History

The past history can easily be disposed of by three pertinent questions: "Have you had any operations, accidents, or illnesses?" If the answer to these three questions is "No," it is apparent that the individual has always been fairly well. However, the details must be elicited if any of the answers are positive. For example:

Operations The nature of the operation, the date, the hospital, the anesthesia, and the surgeon should be recorded, as well as the duration of the hospital stay. *In investigating male sterility, it is frequently necessary to communicate with the* hospital or doctor to get a written report of the operation and pathologic findings.

Accidents. Accidents should be recorded in detail, particularly those that had to do with head injuries, including concussion or loss of consciousness, with potential residual damage to the pituitary or hypothalamic area. Injuries in and around the pelvis are important as regards trauma to the external and internal genitalia. *However, if the male has received a blow in the scrotum, with resultant hematoma* formation or swelling of the gonads, it does not mean that he is sterile. Torsion of the testis, on the other hand, is an entirely different type of trauma and frequently results in loss of the function of that gonad.

Illnesses. The illnesses of a serious nature that are important are pneumonia, tuberculosis, streptococcal infection (particularly of the upper respiratory apparatus), local infections relative to the groins, external genitalia, prostate, bladder, and skin. Chronic disease of the scrotal skin results in elevated temperature of the scrotum and its content, and many patients with skin diseases of the groin or scrotum have had roentgen treatment, often without protection of the gonads. A history of roentgen therapy itself should be sought, with the time, the date, the duration, the amount of radiation, and the doctor administering treatment. The usual childhood diseases should be noted, with particular attention to mumps and whether or not the mumps involved one or both gonads. Diabetes must be ruled out.

To be sure, there are many males whose alcoholic habits exceed what we consider to be excessive, but who do not complain of infertility. Perhaps that portion of the medical profession that does not consider alcohol important does not have to see and treat the male population complaining of lessened fertilizing capacity and, therefore, believes these points to be unimportant. From the standpoint of improving physical fitness, however, the medical group usually recommends temperance. In other words, if the husband drinks some alcohol daily, he is urged to stop for at least a three-month period. If he drinks moderately, once a week or less, he is advised to stop, but not urged to. The reverse is true occasionally in cases where psychologic factors seem to interfere with the male's wooing and winning capacity and when the relaxing effect of alcohol builds up his courage and lowers his morale to the point where normal sex behavior is not considered wrong or immoral.

Excessive use of coffee, tea, and other stimulants is also deleterious to the spermatogenic function and if the history records the incidence of intake of more than one cup daily of these beverages, steps should be made to correct this. The soft drinks themselves are not free from suspicion, for it has been common practice for workers in factories and large office buildings to consume three to six bottles of soft drinks a day. Moreover, a recent article states that the excessive consumption of soft drinks may cause damage to the liver.

Drugs. In recording the history, one should normally elicit the intake of various medications proprietary and otherwise, to which the individual has been habit- [illegible] Other patients have been taking various proprietary remedies for the relief of hay fever over long periods of time, even in the form of injections of substances which may be deleterious or harmful to their general efficiency from the reproductive point of view. Patients with peptic ulcers frequently consume abnormal diets, which are compatible with normal health, but not with reproductive capacity, over long periods of time. Faddists may go for years without proper protein intake. As the medical literature implies, increasing consumption of sedatives of one sort or another is a noxious influence on the reproductive capacity, if for no other reason than that they alter the general physiology. To be sure, occasional sedatives are indicated to relax a tense individual, working under a terrific load, who finds it impossible to relax and get enough sleep.

Hormones. It is necessary to go into detail as to the amount and type of hormones that have been administered to the individual before he comes to the present examiner. Many males have taken old-fashioned oral preparations of whole glands which are technically of no value whatsoever. Others have been given large doses of gonadotropic hormones or testosterone parenterally for long courses of treatment There is no doubt that testosterone in adequate amounts will cause azoospermia in an individual who had some sperm before the program was started, and it has been established that chorionic gonadotropic hormones in adequate amounts may lessen one's spermatogenic function. It may take some weeks to months for the harmful influences of these medications to disappear and enable the examiner to get the proper assay of the male in question from his semen specimen.

Genito-urinary Symptoms Does the patient suffer from any nocturia, dysuria, frequency, or hematuria? Here one can introduce queries related to the sex life, as well as details of venereal disease and treatment. Congenital anomalies frequently appear in the history here.

Neurologic Signs. Are there headaches, dizzy spells, spots before the eyes, nervous disorders, or epilepsy? These should be the contributions by the patient of his neurologic past, that frequently do not come out in the first interview.

RECORD OF HABITS

Tobacco. It is necessary to be specific as to the amount of tobacco consumed daily, the number of years it has been used, and the effect on the individual as regards loss of appetite, easy fatigability, and headache. The effect of tobacco on reproduction has often been mentioned, but it is difficult to prove its deleterious influence. There is little doubt that the consumption of more than 20 cigarettes a day is excessive smoking as regards the general health, to say nothing of the reproductive pattern in some cases.

In selected cases it has been quite apparent that a low sperm count, lessened motility, or too little seminal fluid will respond to the rigid avoidance of nicotine in any form on the part of the patient. This is particularly true in those patients whose work is indoors, sedentary, and productive of severe mental fatigue. It is not uncommon to find business executives, teachers, and stock, bond, or insurance salesmen whose daily ration of cigarettes runs between 40 and 50.

The history should include the number of cigarettes smoked daily and also how many years the man has used that amount, whether he has ever stopped smoking for more than one month without good result, and what other symptoms he has noticed from excessive smoking It is our practice to require all men who definitely want to improve their reproductive capacity to stop smoking entirely or certainly to limit their consumption to fewer than 10 cigarettes daily.

As regards pipe tobacco, cigars, and chewing tobacco, the same observations hold but to a lesser degree. The aim here is extreme moderation rather than complete abstinence. In underweight patients, ulcer problems, and those who sleep poorly or eat poorly, remarkable improvement will result from strict self-denial.

Alcohol. The excessive consumption of alcohol in any form has been noted for years as hazardous to proper spermatogenesis. All agree that the acute or chronic alcoholic and others who abuse this social practice may have lowered fertility. This is presumably due to the toxic influences of alcohol on the system in general and the spermatogenic cells in particular. Alcohol has been demonstrated to be excreted by the prostate and the urinary tract. This does not provide a suitable medium for the sperm. The end result is lowered efficiency on the part of the male who overindulges in drinking.

It is wise to record the frequency of alcoholic intake, the amount consumed, and over how many years If the individual drinks daily and has done so for three to 10 years, he may have a less efficient reproductive system than a man who does not drink. It is probably sounder to indulge in several drinks over a week-end after which the system is washed free of these impurities than to have two glasses of wine, cocktails, or whisky daily.

particularly confusing because of the war years, as many men have been working overtime to make up for the time lost in the armed forces. If, as is often the case, the husband has taken no vacation in six or eight years of marriage, and has been working under severe business strain, with attendant family responsibilities, frequently of an emotional nature, the absence of vacation of any form is important. Certainly, the minimal fair vacation for the individual trying to maintain a proper physical and mental capacity not disturbed by chronic fatigue is two or, preferably, three weeks, and for those engaged in mental work, four weeks. This should be either in the form of 30 days off per year, or four 10-day periods at separate times during the year.

The history may uncover the fact that the individual takes adequate time off from his work, but utilizes that time in extracurricular activities of a pressing nature, such as charitable or religious organizations, lodge and club activities, etc. It is obvious that a person whose working days are spent driving a car or traveling, does not get much change in his environment by taking a trip in a car or traveling for his vacation. It is also evident that the average worker does not get much change in his environment if he takes his vacation by remaining at home doing work about the house. A change of scene and activity is as important as freedom from work.

Diet. Careful record of the food consumption should be obtained. This can be done quickly by inquiring if the individual has a glass of milk, fresh fruit, two vegetables, meat or fish, at least one egg, salad, and cereal daily. If the diet is deficient in any of these items, it should be corrected. If the diet reveals a marked increase in caloric consumption and low protein intake, this should also be corrected. If the individual eats no breakfast, a sketchy lunch, and an enormous dinner, or eats a small breakfast and no lunch, regular habits of eating should be stressed.

It is fairly well established that the digestive processes handle small amounts of food at regular intervals better than large amounts following long periods of fasting. If the medical, nutritional, or dietary history reveals inadequate intakes of vitamins and minerals, appropriate adjuvant therapy, in the form of pills or capsules, may be indicated. The finding of the apparent lack of vitamin A or E, or even B, C, and D, in the history, indicates the necessity for the administration of adequate vitamin therapy. However, it has never been established that the administration of all the vitamins, A through E, will be rewarded by *prompt reproductive* results. Here again, the literature is full of articles demonstrating the value of vitamins, but without any adequate proof. All authoritative articles on vitamin E, in particular, indicate that administration of this vitamin has never been proved of value in the restoration of male reproductive capacities.

Miscellaneous Conditions

Isolated but important factors in certain cases include several important instances of the following, and if the history elicits such, a special search must be made of these cases.

Influenza is said to cause blockage of the vas deferens.

Chronic prostatitis is extremely common, and responds favorably to massage at weekly intervals.

Habits of Sleep. It is important to record the time an individual goes to bed and the time he gets up, thus estimating the amount of sleep that he gets per night. How that patient sleeps should also be recorded. If an individual works on a night shift and sleeps from 7 A.M. to 3 P.M., everyone will agree that his sleep

[illegible]

Coital Habits Having guided the patient into bed by this approach, it is easy to turn his attention to coital habits. How often is intercourse practiced? The reputed average is two or three times a week Is it satisfactory to the husband? It usually is. Is it satisfactory to the wife? It frequently is not. At least 40 per cent of wives are said to get no satisfaction from intercourse. What position is used? The usual position is that in which the wife is on her back, the husband above. Variations, and reasons for them, should be noted. Has contraception been practiced? If so, what kind, how long, and is it invariably or sporadically used? How long ago was contraception abandoned? If it is more than one year the patient deserves careful study. If it is less than one year, it is probably sufficient to ascertain whether the individual has been exposed at the right time of the cycle often enough to promote pregnancy. If that is not the case, give appropriate advice regarding the fertile time as evidenced by basal body temperature recordings over a three-month period, and then pick up the threads of the study from there. How often was intercourse indulged in in the first two months of marriage? If the answer to this is nightly, or more than nightly, careful attention should be paid to the husband's seminal fluid, as some males become either aspermic or oligospermic by sexual excess Here too, one may learn that intercourse was impossible during the first two months of marriage There are various reasons for this, sometimes psychologic angles from the husband's point of view, and sometimes physical angles from the wife's point of view The first few months of marriage are often decisive in determining the couple's frequency of intercourse and subsequent fertility.

All of the above questions in this section require careful, gentle, but persistent, pursuit until they have been satisfactorily answered. Ordinarily these questions are run-of-the-mill, and adequately answered by a patient on the initial interview. However, it is pertinent to see the wife also, as an entirely different story may be elicited from her Furthermore, after the physician has become better acquainted with the patient, he may find occasion to go back to this section of the history, and may collect details which did not come out at the initial interview.

Exercise. A record should be made of the habits of the individual, relative to exercise now and in the past. If he was highly athletic up to and including six years prior to the interview, and then initiated a sedentary existence, his physical fitness has definitely waned, and possibly his reproductive capacity. If an individual is extremely athletic, overdoing it, as it were, or if he is in his fourth or fifth decade, moderation should be introduced The sedentary situation will be more likely, however, and will require the appropriate attack. Careful searching for this type of history is important in selected cases

Vacation. The amount of vacation an individual takes each year should be recorded and also the number of years he has gone without vacation. This is

Chest

Examinations should include observation of the distribution of body hair, the presence or absence of gynecomastia, as differentiated from subcutaneous fat in the region of the areolae of the breasts, and the search for scars. Routine observation, of course, on heart, lungs, and blood pressure is recorded.

Abdomen

The distribution of hair and pubic hair, the presence or absence of scars, obesity, tumors, or signs of malnutrition are important. Occasionally a patient fails to recall an early hernia or operation for bilateral hernia, which may be the clue to his resulting azoospermia.

External Genitalia

With the patient lying down, the examiner should study the external genitalia by inspection and palpation, noting the size of the penis, scrotum, testes, and accessory sexual apparatus. It is easier to palpate for the presence or absence of the vas deferens with the patient recumbent, and there is an increasing incidence of the absence of the vas deferens either unilateral or bilateral as the examination proceeds. One can also feel beading in the vas deferens in cases of gonorrheal involvement of that structure. Occasionally the individual has had a vasectomy and the blunted ends of the divided vas may be palpated subcutaneously. The size and consistency of the testes can be noted and approximately recorded in centimeters There is a need for a satisfactory measuring device for the gross testes in situ. One often discovers that the testis is abnormally large, but transillumination will reveal the presence of a hydrocele encircling the gonads and actually a small gland. A search for tumors of the testes, epididymis, and associated structures is fortunately not often rewarded by the finding of one, but in routine studies, testicular tumors are picked up with sufficient frequency to make the search an essential requirement at this point. Any suspicious tumor in the testes, in its accessory structures, or in the scrotum itself, should be promptly submitted to surgical excision for microscopic evaluation. It has been the writer's privilege to effect a cure in a man with a malignant testicular tumor, whose initial mass measured 1×0.2 cm , as a hard, fixed, nontender nodule in the region of the left vas and epididymis Surgical excision revealed a seminoma, and the first operation was followed by orchidectomy and subsequent radiation in July, 1942. The patient still is alive and well. He and his wife have adopted 2 children, and have a happy family life. It cannot be too highly emphasized that, even though the examiner feels that the nodule in question is not a tumor, the only safe method of handling the problem is surgical excision and adequate microscopic studies. In other words, the finding of an unsuspected tumor precludes further sterility investigation until the absence of malignancy has been determined surgically and microscopically. The patient should then be examined in an erect position and again, after the inguinal rings have been checked, observations are made relative to the penis, scrotum, and its contents, with the patient standing. Here varicocele will present itself for the first time and occasionally maldescent of the testis becomes more apparent. There is an emotionally unstable type of

Stricture of the urethra is uncommon except following trauma, instrumentation, or gonorrhea, and can be suspected from the history.

Premature ejaculation, while frequently a complaint, is not important unless the Sims-Huhner test is negative, which implies that there is no insemination of the cervix.

Dyspareunia, due to painful reaction on the part of the male, may also be caused by balanitis, *Trichomonas vaginalis,* sensitivity to rubber, sensitivity to various chemicals, venereal warts, or just plain trauma.

Dyspareunia may also be the result of painful reaction on the part of the wife from too small an introitus, lack of lubrication, faulty technic, *Trichomonas vaginalis,* and other forms of vaginitis acquired from or transmitted to the sexual partner.

Faulty insemination after lumbar sympathectomy, following the injection treatment of hernia, and, rarely, sterile motile spermatozoa, are reported.

Impotence. This rare condition in couples complaining of infertility requires a complete study of both partners and frequently the aid of a psychiatrist. It requires tact, patience, and understanding as well as time on the part of the doctor.

Coitus inter Femores. This practice requires treatment of wife and husband, and a considerable amount of time devoted to the education of the couple.

COMPLETE PHYSICAL EXAMINATION

The individual should be prepared for a complete physical examination, and should produce at this time a specimen for urinalysis. This guarantees an empty bladder, which is just as important in the male as one approaches the pelvic region, as it is in the female before pelvic examination, and creates an element of relaxation which does not exist when there is a full bladder. The patient should be stripped to the waist, or preferably completely stripped. In the course of the routine physical carried out in the customary manner, particular attention should be directed to the following items: general body build and configuration, span, fat deposition, distribution of hair, growth and size of external genitalia, size of prostate, and the presence or absence of scars, tumors, and gonads.

Head

The amount of temporal recession of the hairline should be recorded, as many eunuchoid or hypogonadal individuals do not have recession of the temporal hair. Record the presence or absence of baldness, the amount of beard, and the age at which shaving became necessary. Note the reactions of the pupils to light, the deviation of the nasal passages, the status of the throat, tonsils, and teeth. Some men have a considerable amount of dental work or capped teeth and roentgenograms may reveal silent abscesses of the teeth.

Neck

Note the presence or absence of cervical glands, the thyroid, and/or scars.

column of blood upon the left testis, but because the stagnant column of blood serves as a heat supplying source not only to the left gonad but also to the right which lies in juxtaposition. Furthermore, if the individual is aware of the varicocele and has symptoms from it, he is rather prone to wear a suspensory for long periods of time, even at night, and this interferes with the thermoregulatory mechanism of the scrotum, an increasing factor in the causation of male infertility. The treatment of varicoceles will be taken up later. Lesions of the scrotal skin of

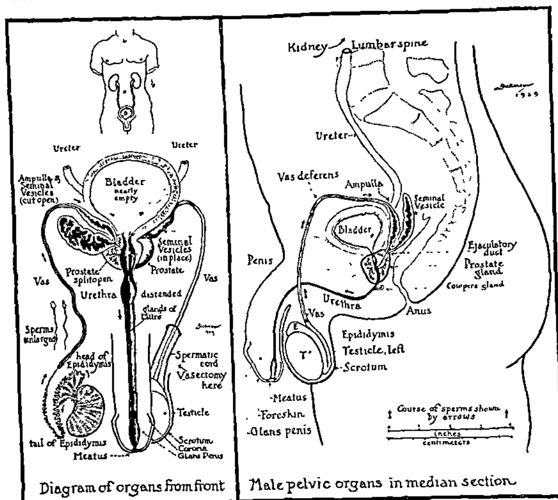


FIG. 2 —Male genito-urinary organs Note the relative size of the lower pole of the epididymis, lumen of the vas deferens, and orifice of the ejaculatory ducts to the urethra.
(Dickinson, R. L *Atlas of Human Sex Anatomy.* Ed. 2, Williams and Wilkins Company, 1949.)

a dermatologic nature should be noted and a dermatologist's opinion should be sought. Rarely does an individual present himself for study who is unaware that he has bilateral undescended testes. If the individual is past the age of 16, further relief of his infertility is not indicated Careful palpation of the vas deferens and epididymis will pick up most cases of gonorrheal epididymitis with attendant azoospermia. At this point in the physical examination it is also well to record the presence or absence of what is called "skin-tight underwear," the jockey type of shorts or suspensory type of underwear, which prevents the testis from experienc-

patient in whom, as he stands erect, one observes that the testes are held close to the body by hyperirritability of the cremasteric reflex. This may influence the scrotal temperature. If a varicocele is discovered, the patient lies down again and

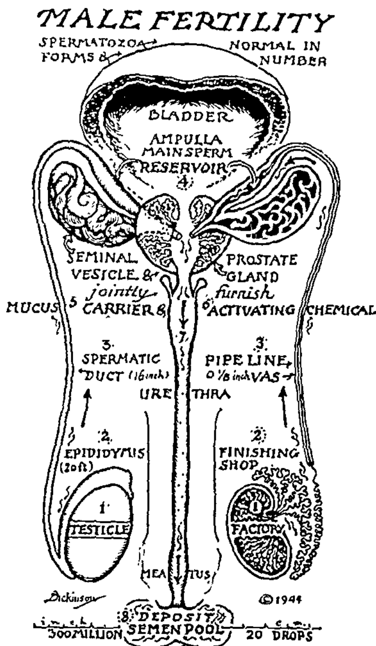


FIG 1 —The male genito-urinary organs in median section
(Dickinson, R L *Atlas of Human Sex Anatomy* Ed. 2, Williams and Wilkins Company, 1949.)

a note is made as to its size Varicoceles are classified as small, medium, or large Probably small and medium varicoceles are not responsible for a patient's infertility, but a so-called large varicocele may be a factor in influencing the spermatogenesis of the individual, not so much from the standpoint of pressure of this

ing its normal thermal environment as regulated by the dartos musculature. It is probable that deleterious influences affecting the thermal mechanism of the scrotum may adversely affect the spermatogenic function of the individual even though he has a normal sperm analysis. In *9 of 50 men presenting themselves* complaining of infertility, the observation was made that "skin-tight underwear" had been customarily worn for from three to 10 years.

The penis is inspected, the individual is instructed to retract the foreskin, notes are made regarding phimosis, paraphimosis, epispadias, hypospadias, and the size of the urethral meatus and of the flaccid penis. In cases of suspected phallic inadequacy, it is possible to obtain accurate measurements of the erect organ by instructing the patient to draw on a piece of cardboard a pencil outline of the erect organ, by placing the cardboard beneath the penis, close to the scrotum, and using a pencil to outline the organ on the piece of cardboard.

According to Dickinson, the average length of the erect phallus is 6.3 in., or 16 cm. Kinsey reports 6.2 inches. The average measurement for the diameter of the midshaft of the phallus is 1.25 to 1.5 in.

PROSTATIC EXAMINATION

The physical examination usually terminates with a digital rectal examination to explore the prostate and seminal vesicles. This is best done with the patient bent forward so that his elbows rest on the table while the gloved and lubricated index finger is gently introduced through the anal sphincter. At this time inspection is made for hemorrhoids, fissures, and pruritus ani. The finger sweeps over the entire prostate and vesicular area in a gently massaging manner which normally causes the production of a copious amount of prostatic fluid per urethram. Since the man has been provided with a glass slide he is instructed to catch the fluid on the slide. Examination of this fresh material is made microscopically at once and the record made of the presence or absence of white blood cells, red blood cells, sperm, and other cells. Often no secretion is obtained on the initial visit. The test should be repeated. It is the author's opinion that in the absence of recent emission of fluid, failure to secure fluid on a properly performed massage indicates paucity of the accessory sexual gland secretions and is more commonly found in infertile males. As in all of these tests, however, conclusions should not be drawn from an isolated trial.

The fluid is then smeared on the slide, dried, and sent for gram stain examination. This massage must be routine and the findings are often revealing.

TESTICULAR BIOPSY

Since Hotchkiss introduced the technic of testicular biopsy in 1939, the author has had occasion to do over 460 cases, many of them repeated after various forms of therapy. It is a distinct contribution to the investigation of the infertile male, as well as to the study of endocrine problems. If introduced early enough in the puberal and postpuberal years, it may be possible to learn more about spermatogenesis, and the indications for hormonal therapy. In all of the cases of obstruction, which numbered over 25, the testis revealed normal spermatogenesis, in spite of obstruction varying in duration from one to 29 years. Nine cases of congenital

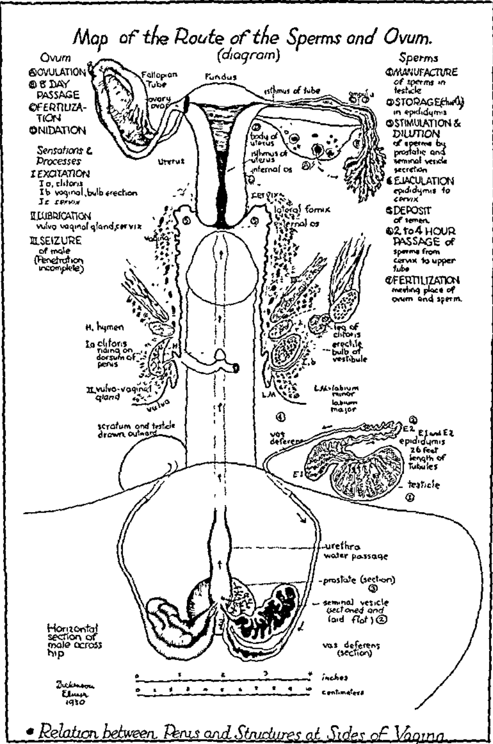


FIG. 3.—Pathway of sperm from the site of origin to the goal (Dickinson, R. L.: *Atlas of Human Sex Anatomy* Ed. 2, Williams and Wilkins Company, 1949.)



FIG 6.—Spermatogenic arrest The tubules are normal in size, there is no thickening of the basement membrane The primary and secondary spermatocytes appear normal, but there is a generalized "arrest" at spermatid formation Few to no mature sperm are seen These cases, 16 in number, have responded as yet to no form of therapy.

(Howard, R P, Sniffen, R. F., Simmons, F. A., and Albright, F *J. Clin. Endocrinol* 1950)



FIG 7.—Progressive tubular sclerosis (Klinefelter syndrome). There is marked diminution in the number of tubules; some are completely wiped out; some are almost obliterated by marked thickening of the basement membrane There is no spermatogenic activity and there is an apparent increase of the Leydig cells, amounting almost to hyperplasia. The fertility is 0 and the prognosis for restoring spermatogenesis is thus far 0 in our hands.

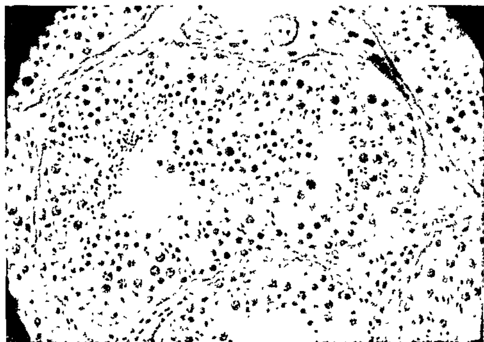


FIG. 4.–Normal testicular biopsy. The tubules are uniform in size, there is normal progression of spermatogenesis from the large primary spermatocytes near the thin basement through the mass of the tubule to the lumen where the little black dots are mature sperm. The Leydig cells appear normal.

(Howard, R. P., Sniffen, R. F., Simmons, F. A., and Albright, F.: *J. Clin. Endocrinol.* 1950.)

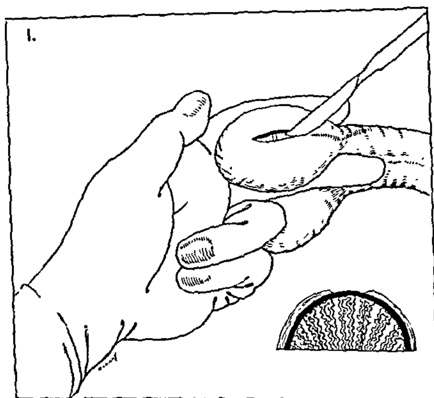


FIG. 5.–Complete aspermatogenesis. Here too the tubules are uniform in size, but they are devoid of any spermatogenic cells. The long thin cells resembling the spokes of a wheel are the Sertoli cells which provide nutrition and support to the germinal epithelium and are normally compressed by it. Clinically none of these cases respond to any form of therapy. This biopsy illustrates at once the type of male who can be advised to interrupt the sterility investigation and make plans for adoption.

(Howard, R. P., Sniffen, R. F., Simmons, F. A., and Albright, F.: *J. Clin. Endocrinol.* 1950.)

Author's Technic for Testicular Biopsy

Biopsy of the testis is a simple innocuous procedure that may be carried out in the office, outpatient department, or, preferably, a small operating room. Local or pentothal anesthesia suffices. The patient is immediately ambulatory and loses little time from work. The male is placed on the operating table with no preparation except a soap and water scrub and suitable antiseptic to the scrotal skin, and draped. The testis is grasped between the first and second fingers of the left hand (Fig. 9), under gentle but definite tension so that the scrotal skin is placed on the



... down to the tunica interna covering the testis in the depths of the wound, as shown by the curved black line in the schematic cross section. Under novocain or general anesthesia, the procedure is essentially painless.

stretch and the testis is taut beneath the skin. After novocain infiltration (or general anesthesia), a small scalpel incises the skin and subcutaneous tissue down to the tunica externa for 2 cm. This is gently incised and a drop of clear fluid is seen exuding, which identifies the opening of the sac. The clear shiny surface of the testis appears in the depths of the wound.

After increasing the tension of the left hand to fix the testis in the incision, one gently incises the tunica interna 1 cm. (Fig. 10) which allows the tubules in a mass to be squeezed gently through the opening.

In Fig. 11 the tubules are seen to extrude through the wound and it is possible with the testis firmly grasped by the left hand to trim off a piece of tubular mass

obstructive anomalies have been picked up, with normal spermatogenesis still going on in the testes. Figure 4 illustrates the normal appearance of the testis. If an individual has no sperm, and shows a testis as indicated in Figs. 5 and 6, it is obvious that no hormonal therapy is indicated and his case is hopeless, as far as fertility is concerned. In our series we had 18 such cases, and in none has any form of treatment improved the problem of the spermatogenic arrest. Figure 7 shows the appearance of the testis in men who have what is called Klinefelter's syn-

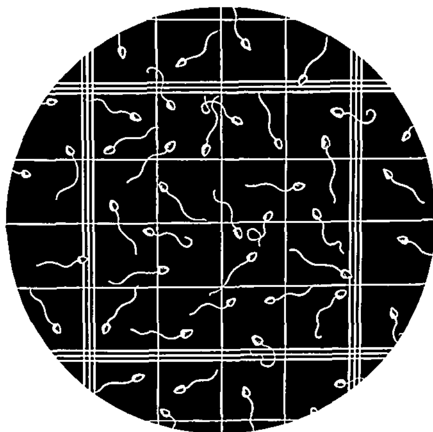


FIG 8—Sperm suspension in one square of red blood cell field of a counting chamber. × 440 (Hotchkiss, R S., *Fertility in Men* Philadelphia: J B Lippincott, 1944.)

drome, which usually consists of gynecomastia, small testes, and a high level of follicle stimulating hormone in the urine. These cases may still show this microscopic picture in the testes in the absence of either small testes or gynecomastia, or high FSH, as Nelson and Heller have shown. Thus, in males who have no sperm it is possible by one simple procedure, namely testicular biopsy, to state definitely that therapy is of no avail and the individual is saved much time and expense. He has found the cause of infertility, and can promptly turn to other solutions, such as heterologous artificial insemination or adoption.

or masturbation, in a clean dry bottle, after an abstinence period of five days or more, and delivered in the office within two hours of the time it is produced. It is further essential that at least two specimens be examined if the first is not normal in every respect. Analysis of the semen is not considered normal if there is too little or too much volume, increased viscosity, too little motility, too few sperm per cubic centimeter, or per ejaculate, and too few normal forms. Since the most important single item in the assay of male fertility is the semen analysis, correct instructions relative to correct collection, correct examination, and correct interpretation are a sine qua non

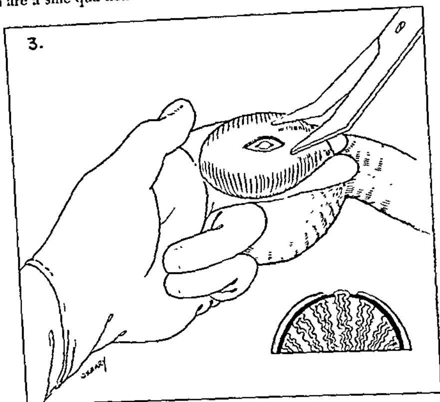


FIG. 11.—Testicular biopsy, author's technic (step 3): A bead of tubular mass the size of the head of a kitchen match is trimmed off with the curved iris scissors as it is squeezed through the tiny incision of the tunica interna. Cross section shows only one tubule. In fact, the tissue secured should contain six to 10 tubules in cross section microscopically. Pressure is then relaxed and the tubule mass and testis itself retract within the scrotal sac. No sutures in the testis are necessary. The skin is closed with one or two black silk stitches.

METHODS OF COLLECTION

The patient is verbally instructed by the doctor to refrain from intercourse for five days, then on the morning of the appointed test to have intercourse as usual, to withdraw at the appropriate moment, and to ejaculate into a clean, dry, wide-mouthed glass receptacle with a cork stopper or a screwed-on top. He is to note whether he spilled any of the specimen. The specimen is to be delivered within two hours of the time of its collection, right side up, to the office. It should be kept at the environmental temperature, and no effort should be made to keep the specimen at body temperature. Specimens in our laboratory collected in any other type of container are discarded and the test is repeated. The specimen is then examined

the size of the head of a kitchen match. A special curved ophthalmic iris scissors is used to secure the biopsy. The tissue is immediately placed in a fixative of 1 per cent glacial acetic acid in Zenker's solution before it dries out. The tension maintained until now by the left hand is relaxed and the tubules drop back within the testis. The testis retracts within the skin. There is usually little or no bleeding but this is watched for. If necessary, pressure or a fine silk tie will control the bleeding. No sutures are placed in the testis. The skin is closed with one black silk

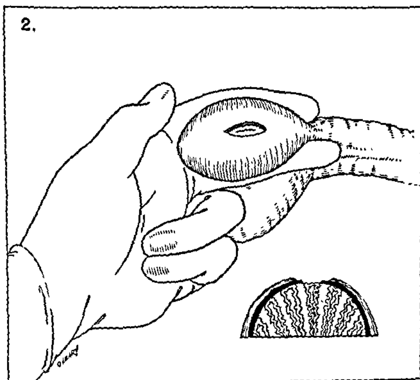


FIG 10 —Testicular biopsy, author's technic (step 2)· A 1 cm. incision is made with a scalpel through the tunica interna as more pressure is exerted by the compressing left hand This opens the testis itself and the yellow substance of the tubular mass presents itself There is usually no bleeding unless a definite vessel is divided Cross section shows the depth of the wound

stitch. Dry sterile gauze in quantity is applied and the surgeon himself adjusts a properly fitting suspensory to the scrotum This holds the bandage in place and provides a good pressure dressing.

The dressing is left alone for five or six days when it is taken down and the stitch removed. There have been no complications except minor bleeding in over 500 operations. The procedure can generally be done on one side only if the testes are grossly similar, but if they differ, biopsies of both should be done.

TECHNIC FOR SEMEN ANALYSIS

Almost all authorities now agree on the bottle method of collecting semen, despite the frequently noted textbook recommendation that collection via condom or prostatic massage may be adequate. It is essential that the examining physician understand that the semen must be collected as described below, by withdrawal

TABLE II

SEMEN ANALYSIS

(Modified from Williams and Weisman)

NAME .... REFERRED BY ....
ADDRESS .... DATE .. ..
AGE .... TIME OF ARRIVAL OF SPECIMEN ....
NO. OF DAYS SINCE LAST EJACULATION ....

Method of Obtaining Specimen:

(Please check box)
1. *Manual ejaculation at lab. into glass jar* ... . ☐
2. Coital ejaculation and withdrawal into jar .. .. ☐
3. Condom method used in collection . ... ☐

Date of Ejaculation:
Exact Time of Ejaculation.
Time Elapsed Between Ejaculation and Arrival at Office.
Approximate Temperature Outdoors:

Physicochemical Test *(Normal)*
1. Volume .... (3 to 5 cc.)
2. Turbidity .. .. (milky opaque)
3. Viscosity .... (After liquefaction, easy flow)
4. Phalanx Formation .... (Present)

Microscopic Evaluation of Spermatozoa.

1. Number per cc. .... (60,000,000)
2. Morphology:
   (from living and stained specimens)
   a. *Percentage of abnormal forms* ....% (less than 30 per cent)
   b. Differential count of abnormal forms
      i Pyriform heads ....% (less than 9 per cent of total)
      ii. Microsperm ....% (" " 12 per cent " ")
      iii Megalosperm .... % (" " 5 per cent " ")
      iv. Miscellaneous abnormalities . . ... % (" " 4 per cent " ")
      v. Abnormal acrosomes . .. . % (" " 5 per cent " ")
3. Number Dead on Arrival .... % (" " 30 per cent)
4. Comparative Motility:
   i. Motionless (dead) ....% (" " 30 per cent)
   ii. *Moderate motility or swift moving* .... % (at least 70 per cent)

Microscopic Evaluation of Formed Elements Other Than Spermatozoa:

(Please check)

Pathologic Findings	*Normal Findings:*
1. Specific bacteria in large numbers.	1. Skin bacteria ....
2 Leukocytes–large numbers	2 Occasional . ...
3 Red blood cells	3. None ....
4. *Epithelial cells in large numbers* ..	4. *Occasional* .. . .
5. Mucus in increased amounts	5 Mod. amount of mucus ....
6. Crystals in fresh specimens	6 Crystals after standing ....

Endurance of Spermatozoa:

At room temperature (20-30° C) .... hr (should show motility *for 24 hr.*)

Summary of Significant Findings.

1. .. ..
2. .. ..
3. ....
4. ....

IMPRESSION.

Signed .... M D.

at once for the appearance, color, consistency, and volume. Viscosity is described as normal or increased as a bacteriologic loop of seminal fluid is withdrawn from the glass receptacle after the specimen has been agitated. A hanging-drop preparation is then made, which is the first microscopic study. It is placed under the microscope and examined under low and high power for the degree and percentage of motility. Although there are elaborate methods to determine the motility, a reasonable amount of experience enables the same observer to be fairly constant in his appraisal of the percentage of living and motile sperm by this means. It is often desirable to cut down the field of the microscope by covering three-quarters of the eyepiece with a piece of black paper, allowing a quarter of the field to be examined at one time. If the specimen contains what seems to be 60 per cent or better of actively motile sperm at the end of two hours, it is considered normal.

Farris has contributed a new method of motility determination which is valuable and offers great promise. It has not been available long enough for inclusion in this paper, and the reader is referred to the original article for the technic. It is satisfactory to carry out the examination of the specimen by both the Farris technic and that described here, one serving as a check on the other.

Blom, of Denmark, has recently introduced a new stain which determines the percentage of living sperm, and also gives one some idea of their degree of viability This, also, is too recent to be evaluated properly here. However, it deserves study Williams has found this a valuable contribution to the study of semen, and proposes to review this additional method of determining viability and motility as this is written.

In our method, a comment is made regarding the presence or absence of phalanx formation. Its presence is considered normal; if it is absent, the sperm are considered less than normal. Phalanx formation consists of the lining up of the spermatozoa around the periphery of the drop, as if they were all trying to get outside of the drop. This was first brought to the writer's attention by Dr. John Rock, at the Free Hospital for Women. It serves as an added gauge of the normality of the motility of a given specimen.

Reference to the modified semen record (Table II), as suggested by Weisman and Williams, will be self-explanatory as regards various other details of the semen analysis and its record. The other two important items are the actual count or density of spermatozoa per cubic centimeter, or total ejaculate, and the stained morphologic differential record.

SPERM COUNT TECHNIC

The majority of examiners use the pipette dilution method of sperm count, although some prefer the bulk dilution method. We use the white blood cell pipette and the Neubauer counting chamber for blood cells, as first described by Macomber and Saunders in 1929. The fresh specimen is thoroughly agitated, and then the semen is drawn to the 0 5 mark, halfway up the stem of the pipette. The diluent, which is 5 per cent sodium bicarbonate in 1 per cent formalin (equal parts) is then used to fill the pipette to the 1.1 mark. The pipette is thoroughly shaken, as in doing blood counts. The diluted fluid is then loaded on the blood counting chamber and the cells are counted as in a red blood cell count, using five blocks of 16 squares. All of the spermatozoa lying within these squares, and

Elaborate staining technics and elaborate classification of spermatozoa exist, but they are outside the scope of this presentation. The author prefers the simple classification, as depicted in Fig. 12, from Weisman's text. Twenty-five years ago, Williams stated that, "the morphology of the head of the sperm constitutes the greatest single source of information for the fitness of the cell for reproduction." Many husbands are classified as sterile or normal by the doctor's merely studying a fresh specimen without staining technics. If the examiner will take the trouble to stain a specimen, as described below, the patient will receive a much more accurate prognosis than by merely estimating his fertility.

TECHNIC OF STAINING SPERMATOZOA

We have not found it practical to do the stained smears from a fresh specimen. Following the technic of Williams, we allow the specimen to remain overnight with a few crystals of thymol for preservative under standard refrigeration. This seems to take care of a good deal of the mucus which confuses the staining and obviates the frequent complaint of the casual investigator that attempting to rid the specimen of mucus by dissolving it with chlorozene washes the majority of sperm off the slide. The next day, a thin film of this preserved seminal fluid is placed on a clean glass slide and allowed to dry in air. The following stain was found to be satisfactory for routine office procedure:

KAUFMAN'S STAIN AS RECOMMENDED BY DR. JOHN MCLEOD

(1) 10 per cent formalin
(2) (A) 1 gm. hematoxylin } Dissolve in oven
50 cc. 95 per cent alcohol }
(B) 50 gm. alum. ammonium sulfate
1000 cc. distilled water
(Mix the above solutions and add 5 cc. of distilled water.)

Staining Technic:

(1) Place slide in 10 per cent formalin solution for two to three minutes
(2) Wash in tap water
(3) Place slide in hematoxylin solution for one to three minutes
(4) Wash in warm tap water
(5) Dry and examine under oil immersion lens

(With this stain the nucleus stains a dark blue, the tail a dark blue, and the head a pale pink. The differentiation is clear.)

A differential count is then made under oil immersion lens, 300 cells being counted, and the result recorded in percentages, using Williams' classification as follows:

CLASSIFICATION OF SPERMATOZOA (WILLIAMS)

(1) Normal forms	(at least 70 per cent)
(2) Pyriform heads	(not over 9 per cent)
(3) Microsperm	(not over 12 per cent)
(4) Megalosperm	(not over 5 per cent)
(5) Abnormalities of the acrosome	(not over 5 per cent)
(6) Miscellaneous types	(not over 4 per cent)

those whose bodies overlie the lines on two sides of the squares, are counted. The total number of sperm in the five blocks is recorded and six zeros are added to give the number of sperm per cubic centimeter. Obviously, the measured volume in a cubic centimeter when multiplied by this figure, gives the total count. A 10 per cent error in counting is allowed. If necessary two or more counts may be made from each specimen. When the count is 20,000,000 sperm per cubic centimeter, or less, the margin of error is so great that further attempt at accurate counting is not indicated. Those cases having less than 20,000,000 sperm per cubic centimeter are all classified together with regard to prognosis.

MORPHOLOGY OF SPERMATOZOA

Just as the semen analysis is the most important factor in the assay of male fertility, so the morphology of the individual spermatozoa is the most important single observation to be made about the individual specimen. Credit for determining the fertility of the individual by recognizing the importance of demonstrating the presence of sufficient normal forms should go to Walter W. Williams, who

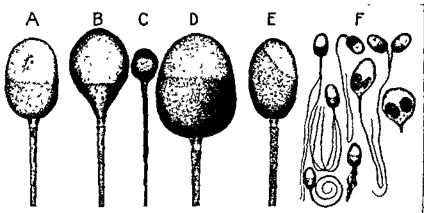


FIG 12 —Classification of morphology of sperm heads after the method of Williams. (A) Normal, (B) pear-shaped, (C) microsperm, (D) megalosperm, (E) abnormalities of acrosome, (F) miscellaneous

(Weisman, A I. *Spermatozoa and Sterility*, New York. P B Hoeber, Inc. 1941.)

initiated the entire study of spermatozoa, working with bull semen in relation to their fertilizing ability, in 1920. Too great a literature on morphology has appeared to be even summarized in this space. The reader is referred to standard texts on male sterility or the papers by Williams for details. It suffices to state that for practical purposes, except for teaching laboratories, research laboratories, or the expert semen analyst, the types of abnormal morphology are not pertinent here, but if there are more than 30 per cent abnormal spermatozoa in the repeated specimens the opinion of one of these experts should be sought

At a recent informal discussion (1949) between 6 or 8 of the leading authorities on semen, it was implied that, if the given specimen contained 70 per cent or more normal forms, the individual was within normal limits. Simplicity in studying the morphology is the goal here, and the average doctor's office can screen individual specimens satisfactorily to see which need the opinion of the expert and which may be called normal early in the investigation

(7) Dilute acetic acid . . . 60 cc.
Distilled water . . . . 60 cc.
Concentrated acetic acid . 3 Gtt.

(This solution need only be used if nuclear material appears overstained. Its purpose is to withdraw excessive hematoxylin.)

(8) Wash and dry. Examine with oil immersion lens.

Method of Williams
(Crystal violet and rose bengal):

(1) Cover film with 0.25 per cent aqueous solution of crystal (gentian) violet for three minutes.
(2) Wash.
(3) Decolorize with 95 per cent alcohol for one minute.
(4) Wash with water.
(5) Counterstain with 1 per cent rose bengal (aqueous) for eight seconds.
(6) Wash and dry. Examine under oil immersion.

Dr. W. W. Williams advocates that Löffler's methylene blue is acceptable as a screening stain, but he emphasizes that there is *no* short cut to studying sperm morphology.

Loffler's methylene blue:

(1) Fix slide with heat.
(2) Stain with methylene blue for two minutes.
(3) Wash and dry. Examine under oil immersion.

TREATMENT

As in most problems, the treatment of male infertility depends on the cause. However, one of the most confusing situations is that there are likely to be multiple causes in the average infertile marriage. As Meaker has pointed out, in most cases there is an average of 4.81 factors in the couple, and 1.61 factors in the males studied. As the incidence of study of husbands in cases of repeated miscarriages increases, more and more male factors will be uncovered.

Prevention of sterility by adolescent hygiene, improvement of health and sex hygiene, control of venereal diseases, and the elimination of improper treatment or *delay in treatment* of the condition itself will undoubtedly result in a higher over-all salvage of human births than therapy after 12 to 24 months of marriage can ever achieve.

If the patient and the doctor are willing to admit that a male must be in the best possible physical condition to solve the problem of his infertility, then it becomes a simple matter to develop the pattern of his treatment. Despite a normal semen analysis, the husband may be the factor in either sterility or frequent miscarriages. The routine treatment is basic, and consists essentially of the correction of faults of diet, exercise, occupation, cohabitation, clothing, and the relief of excesses of nicotine consumption, alcoholic consumption, carbohydrate consumption, and of coital excess.

In the absence of special stains, the Gram stain gives fair results for an initial opinion, as does Wright's stain for blood. However, if doubt exists about the individual and the decision depends on the morphology, the opinion of an expert should be sought. It is apparent that the prognosis depends on multiple factors *in the interpretation of the semen. In fact, as stated earlier, the prognosis should not depend on the semen study alone, but by an appraisal of a combination of* factors, namely, the patient's history, the physical findings, the semen analysis, and other laboratory tests.

Haphazard collections of specimens submitted to haphazard commercial laboratories throughout the land, or to most hospital clinical laboratories, are not a fair assay of a man's fertility. The physician should take advantage of the minimal diagnostic standards proposed by the American Society for the Study of Sterility, and learn to do his own stains, or send them to one of the recognized semen authorities' laboratories which are found in a few large teaching centers.

The controversial aspects of interpretation of the morphology of spermatozoa are at present so acute that the reader is advised to keep up with the current literature, as changes in the technic and interpretation occur rapidly. There is a need for more laboratory technicians in the special field of sperm morphology. The best sources for opinions lie in the offices of these doctors who do their own stained smear analyses or employ a credited semen laboratory. There are many methods of staining of which the following have stood the test of time and of criticism from most other workers Some of these are as follows:

Method of Hotchkiss:

The materials used for the stain are:

(1) Schaudinn's solution	60 cc.
Mercury bichloride 7 per cent	40 cc.
Alcohol 100 per cent	20 cc.
Time· 0.5 minute	

(This fixing solution permits adherence to the slide without heating the smear, and ensures preservation of cell structure. The wet smear is immersed immediately in this solution for the time specified.)

(2) Alcohol 50 per cent	60 cc.
Time: 0.5 minute	
(3) Wash in water	60 cc.
(4) Eosin aqueous 1 per cent	60 cc.
Time· 0.5 minute	
(5) Acid alcohol	60 cc.
Alcohol 50 per cent	
Concentrated HCl 3 Gtt.	
Time: 0 5 minute	

(This solution removes some mucus but leaves the cells intact. If sperm are also washed off, weaken the solution by adding water. Wash.)

(6) Harris' hematoxylin	60 cc.
Standard formula plus 3 Gtt HCl	
Time: Two minutes	

(If solution is alkaline, nuclear material will not accept stain. Wash.)

Bankers, lawyers, scholars, and even doctors may sit for hours, day after day, in an overstuffed chair. They may be obese, sedentary, and overfed, suffer from hypometabolism, excessive tobacco, alcohol, and fat intake, topping off their day by an evening (after too much to eat) reading and dozing, or "televising," until they climb into a too warm bed in a too warm room for too little sleep.

All patients seeking relief from infertility, therefore, should be advised to omit smoking and drinking, eat a high protein diet, take regular exercise, wear proper clothing, be moderate in coitus, and, if indicated, take thyroid under supervision. Regular hours of sleep, and eight hours a night, are advised. An adequate vacation, with freedom from the responsibilities of business or extracurricular duties, is often of inestimable value. Attention should be directed to the thermal factors related to the scrotal environment. The judicious, but adequate, use of thyroid extract is the most important contribution from the hormonal aspect.

Hormonal Therapy

Despite glowing accounts, in all languages, of the relief of male infertility by the injection of hormones, the death knell for their promiscuous and random use has been sounded. Most current claims do not stand up under scrutiny, as the pretreatment data are often incomplete and not properly gathered or controlled. To be sure, the hypogonad male and the eunuchoid type will respond to pituitary hormone stimulation and a few have offspring, but the majority would profit more by attention to hygiene and an intelligent design for living. No husband should be injected or treated by hormonal therapy, until he has had more than one competent sperm analysis, the measurement of the urinary gonadotropins, a basal metabolic rate, and often a properly preserved and interpreted testicular biopsy

Thyroid

If indicated, thyroid should be administered in adequate dosage. Our routine is to start all men on 3 grains of U.S P. thyroid daily, 2 pills with breakfast, and 1 pill with lunch, for at least three months The patient is followed at 10-day to fortnightly intervals by an office visit for a brief interview and resting pulse. This is often a good opportunity to carry out an accompanying prostatic massage. If his weight has dropped 3 pounds in the 10 days, or if his resting pulse is over 100, the dose is dropped to 2 grains a day, and so on. After approximately 100 days, or three months, he is reduced to 1 grain daily, except Sundays, to prevent a cumulative effect. Attention to the patient's observations about himself are rewarded usually by the observation that he would not know that he was taking any medicine, or that he has increased pep and vigor and loss of lassitude. Occasionally this is accompanied by an awakened interest in the sex act, and increased efficiency in its performance. Care is taken to avoid warning the patient of the symptoms he might experience, and it is well known that the majority of patients on this thyroid regime have no complaints. The few who do comment that they cannot take the thyroid are professional workers such as doctors, nurses, clinic workers, or patients who have previously been on thyroid medication for some other reason and have been warned of its possible toxic effects.

Diet

A high protein diet is prescribed, which includes at least one glass of milk, fresh fruit or fruit juice, two fresh vegetables, meat (or fish), two eggs, salad, and cereal daily. Avoidance of carbohydrate is aimed at, and the patient should be encouraged to eat breakfast regularly, even if it requires getting up earlier in the morning.

Exercise

Regular exercise, even if it consists of only 30 minutes of brisk walking daily in any kind of weather, should be instituted. In these days of at least primary school education, the American public has been well inclined by suggestion, if not compulsion, to practice some form of vigorous or routine daily exercise, and some keep it up through the second and third decade. Many college graduates, however, on entering graduate school, and certainly on completing graduate school, cease any activity in the field of sports or regular exercise. It is most common for an ex-football star or crew member to spend the next four to 10 years chained to an office desk, or immersed in books, and as a result gain an undesirable amount of weight. Is it not logical then to direct the therapy toward reduction of this weight by graduated, regular, controlled exercise, and a prescribed diet?

Occupation

Sedentary jobs promote sluggishness of the physiologic processes of the body. Attention to the hazards of the occupation and their correction is indicated. The occupations are too numerous to discuss individually, but a good example of the program to be instituted might be the following:

Truck drivers, traveling salesmen, and taxicab drivers are a typical group who may sit behind a heated motor, with another heater in the front deck for hours, breathing carbon monoxide in excess, adversely insulated regarding the scrotal contents by obesity, warm clothing, skin-tight underwear, and the heat-promoting properties of a foam rubber cushion. If these men smoke excessively (20 or more cigarettes a day), consume an excessive amount of alcohol (daily rations of malt beverages or cocktails), and are obese, it is remarkable that they can reproduce at all. The treatment, to be didactic, is as follows:

(1) Stop the car every 50 miles or every hour (whichever occurs first), get out of the vehicle, and draw several deep breaths, walk around the car, and then resume the trip The car itself should be checked as to leaks in the ventilating and cooling systems, and the eradication of noxious fumes.

(2) Reduce the weight by diet, exercise, and, if indicated, thyroid medication

(3) Abolish warm clothing, skin-tight underwear, and perhaps introduce the use of a straw mat to permit the circulation of air between themselves and the rubber cushion.

(4) Restrict the use of, or omit, tobacco, alcohol, carbonated drinks, excessive coffee, tea, and carbohydrates.

Lead workers, garage and filling station employees, gasoline workers, and tire workers, are often exposed to high concentrations of noxious fumes, and extremes of heat and cold.

In the last decade, each year there has been an increasing number of cases reported of successful treatment of male infertility with the anterior pituitary like substance. The majority of these cases, however, have had other treatment as well, mainly the supportive measures recommended here, often thyroid, changes in coital technic, etc., and it is difficult to be sure that the hormone itself has caused improvement. Unpublished data of the author's include 9 cases of the above 22 men, whose wives have had children after their husbands had taken this hormone but, as mentioned, it was employed in conjunction with other measures as well. Two patients, however, deserve special comment. They had marked oligospermia improved by the administration of the chorionic gonadotropin with the resultant successful pregnancy of the wife. Treatment was stopped, the sperm count dropped down, and three years later both wished another child. Subsequent treatment promptly resulted in another child. These patients were treated in the days before testicular biopsies. With the advent of testicular biopsy as a routine measure in patients with marked oligospermia which does not respond to routine treatment in the six-month period, there has been a marked decline in the number of cases in which hormone parenterally was indicated. However, if the patient appreciates that there is nothing left to do, except to administer this hormone, and is willing to take the risk that it may cause a permanent decrease in spermatogenesis, anterior pituitary like hormone can be administered in doses of 500 International Units, three times a week for 10 weeks. The specimen is re-examined at that time, and if it shows improvement, another course of the 10 week treatment can be given. It should be borne in mind that probably the only hormone with definite value in the treatment of cases of male infertility, except in those thoroughly studied in teaching hospitals or research clinics, which reveal pituitary gonadotropic insufficiency, is thyroid by mouth.

Male Sex Hormones

The administration of testosterone proprionate, pure testosterone, or methyl testosterone by injection is not usually indicated in the treatment of male sterility There is some evidence that small doses, 3 to 6 mg. per day sublingually, may do no harm in selected cases, but it should be tried only when there are available laboratory methods for assaying its results, as regards changes in the testes, the semen count and stain, and the urinary gonadotropic hormones. Unless there is frank glandular deficiency, these hormones do no good in the usual case of impotency, premature ejaculation, or other sexual aberrations in a previously normal male. Their administration may always be effective from a psychologic point of view if it has been suggested that they would be beneficial. The same result can be accomplished by intelligent psychotherapy and good hygiene.

Correction of Local Abnormalities

Penis. Disorders of the penis—hypospadias, epispadias, phimosis, etc.—are all amenable to surgical correction, as is stricture of the urethra, by means of graduated dilatation. In questions of blockage of the urethral pathways by the verumontanum, or the ejaculatory ducts, or by prostatic disease, urethroscopy in the hands of a trained urologist is certainly indicated. The results have not been highly satisfactory. Congenital anomalies require correction.

It is necessary also to be on the lookout for two other groups in this type of treatment. There is the group which has taken thyroid, but in small doses, and in which it has been recorded by the physician or patient that the thyroid did no good. Numerous cases are reported in which thyroid is said to have had a beneficial effect with dosages varying from ¼ grain to more than 6 grains a day. This material is not well controlled, and those who say that thyroid is not effective in the treatment of male infertility cannot be disputed. It has been our experience that the majority of internists, and some endocrinologists, favor such small doses of thyroid as an initial dose that no effect can be demonstrated. The current recommendation for thyroid medication, if it is given at all, is that it should be administered, even though the metabolism may be recorded as normal, and the sperm count normal, if the problem has been one of multiple miscarriages and no other etiologic factor can be found.

Thyroid in the doses of 3 grains daily can be tolerated by many essentially normal individuals without the development of any symptoms, with improvement of the motility of the spermatozoa, and with resultant normal pregnancy, where there have been three or four miscarriages before. Under supervision, it certainly does no harm, and should be tried for over a period of three months to a year. During the three or four months after the initiation of treatment, contraceptives should be used, of course, to prevent another miscarriage until the spermatozoa will have gained a normal metabolism.

Secondly, there are those who have been on such large doses of thyroid for other reasons, for so long, that they are thyroid-resistant, and may even develop myxedema on its withdrawal Some individuals have been given more than 4 grains of thyroid for years, some continue to take it, without their doctor's knowledge, as it makes them feel so much better. These individuals have no symptoms which would lead one to believe that they needed thyroid in the first place But some have been on such high dosage for so long there is evidence that it depresses the thyroid, and its removal may mean that their own thyroid has ceased its production of hormones and the patient may develop symptoms of a thyroid deficiency. This situation has also been found in the female.

Pituitary Gonadotropins

Pituitary gonadotropins, so-called follicle-stimulating hormone fractions and luteinizing hormone fractions, should be avoided as they are prone to set up antihormone formation in most males since they are all of protein derivation. Their use is limited solely to the few men who demonstrate pituitary deficiency by complete laboratory and clinical tests.

Chorionic Gonadotropins

Practically monthly articles appear in the literature reporting satisfactory treatment of male sterility with chorionic gonadotropic hormones, or the anterior pituitary like substances The author has had experience with 22 cases, 9 of which showed marked improvement in spermatogenesis under the medication, or more particularly *after* a course of therapy without impregnation of the wives. The majority of these wives were either infertile, or definitely sterile, and the medication was used some years before the advent of testicular biopsy (1939).

Spermatic Cord Correction. The spermatic cords from the ejaculatory ducts down to the scrotal area itself are beyond the realm of treatment, unless it is possible by vasostomy gently to irrigate the lumen of the vas with normal saline. Stronger substances should not be used, because of their scarifying effect, and the operation of vasostomy should be restricted to those men who have complete azoospermia, with normal testicular biopsies.

Scrotal Contents. The contents of the scrotum are amenable to surgical correction, leaving out for the moment the incurable conditions, which do not necessarily relate to fertility. Obviously, removal or ligation of the vas, epididymis, or removal of the testes is not a treatment for sterility. If there is frank obstruction between the epididymis and the vas, however, the operation known as epididymovasostomy should be offered to the patient, if his wife is normally fertile. It is a mistake to do this procedure unless the wife has had a complete assay of her fertility. Since we have 25 cases with a block due to bilateral gonorrheal epididymitis, who have had testicular biopsies, with the discovery of normal spermatogenesis in the testes, we do not feel that it is now necessary to do a biopsy before attempting the anastomosis if the individual has a frank history of bilateral disease. The results from epididymovasostomy vary in different parts of the country. The profession as a whole has a pessimistic attitude toward it. The advance in technic suggested by Dr. Lewis Michelson, of San Francisco, whose contribution is pictured by the accompanying illustrations and consists of the use of stainless steel wire, as an "internal splint" * is promising. The

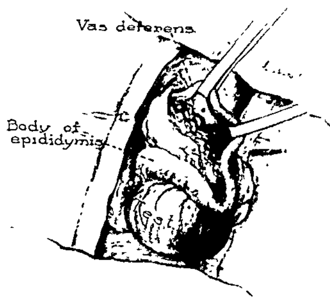
* Michelson's technic is as follows: After the usual exposure and demonstration of patency
oval windows about 0 5 cm

stainless steel wires (No. 36,
stance of about 2.5 to 3.0 cm
d and the wires are threaded
es are then
n the globus
. curved skin
needle and left loose. At the margins of the incision in the vas, four stainless steel wire sutures (40) are *passed through its wall, but not into the lumen* One each at the superior and inferior angles of the incision and one each midway laterally These sutures are then passed through the tunica vaginalis, and several loops of the epididymal tubule at corresponding points on edges of the window, already cut in the globus major The inferior and posterior lateral sutures

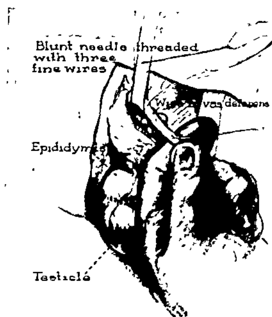
---

FIG 13—Michelson's technic for epididymovasostomy (A) The testicle, epididymis, and cord have been delivered from the scrotal sac The vas has been isolated and held up by umbilical tape. In this and the following figures the vas and epididymis have been drawn disproportionately large. (B) A small incision has been made in the vas Three wires threaded on a blunt-ended needle have been passed through the incision, up the lumen of the vas, and out through its wall (C) The group of three wires has been passed through the incision in the vas, up the lumen, and out through its wall The four wire sutures (1, 2, 3, 4) making the anastomosis are shown (B) Diagrammatic cross section through the vas showing the depth of the anastomotic suture in its wall (C) The oval fenestra has been cut in the globus major, the needle carrying the fistula wires from the vas has been partially passed through the globus major (D) The anastomosis between the vas deferens and epididymis has been completed. The three wires which temporarily maintain the fistula are shown, their course is indicated by the dotted line. The four anastomotic suture wires have been passed and tied Three of them have not been cut and are shown (D) The operative wound in the scrotum has been closed. The ends of the group of three fistula-maintaining sutures have been brought out through the scrotal skin and are held in place by shot.

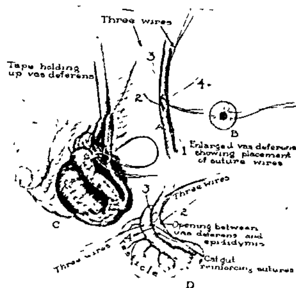
(Michelson, L. Vaso Epididymal Anastomosis. *Surg Gylnec. & Obst*, 82,327, 1946.)



A



B



C



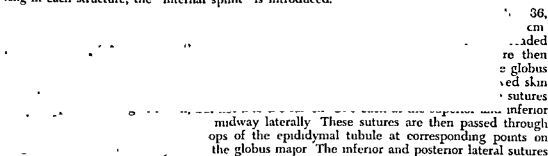
D

Caption on opposite page

Spermatic Cord Correction. The spermatic cords from the ejaculatory ducts down to the scrotal area itself are beyond the realm of treatment, unless it is possible by vasostomy gently to irrigate the lumen of the vas with normal saline. Stronger substances should not be used, because of their scarifying effect, and the operation of vasostomy should be restricted to those men who have complete azoospermia, with normal testicular biopsies.

Scrotal Contents. The contents of the scrotum are amenable to surgical correction, leaving out for the moment the incurable conditions, which do not necessarily relate to fertility. Obviously, removal or ligation of the vas, epididymis, or removal of the testes is not a treatment for sterility. If there is frank obstruction between the epididymis and the vas, however, the operation known as epididymovasostomy should be offered to the patient, if his wife is normally fertile. It is a mistake to do this procedure unless the wife has had a complete assay of her fertility. Since we have 25 cases with a block due to bilateral gonorrheal epididymitis, who have had testicular biopsies, with the discovery of normal spermatogenesis in the testes, we do not feel that it is now necessary to do a biopsy before attempting the anastomosis if the individual has a frank history of bilateral disease. The results from epididymovasostomy vary in different parts of the country. The profession as a whole has a pessimistic attitude toward it. The advance in technic suggested by Dr. Lewis Michelson, of San Francisco, whose contribution is pictured by the accompanying illustrations and consists of the use of stainless steel wire, as an "internal splint" * is promising. The

* Michelson's technic is as follows: After the usual exposure and demonstration of patency of the vas deferens and the globus major and the development of oval windows about 0 5 cm long in each structure, the "internal splint" is introduced.



36, cm ...aded re then e globus ved skin sutures inferior midway laterally These sutures are then passed through ops of the epididymal tubule at corresponding points on the globus major The inferior and posterior lateral sutures

Fig. 13.—Michelson's technic for epididymovasostomy (A) The testicle, epididymis, and cord have been delivered from the scrotal sac The vas has been isolated and held up by umbilical tape. In this and the following figures the vas and epididymis have been drawn disproportionately large. (B) A small incision has been made in the vas Three wires threaded on a blunt-ended needle have been passed through the incision, up the lumen of the vas, and out through its wall (C) The group of three wires has been passed through the incision in the vas, up the lumen, and out through its wall The four wire sutures (1, 2, 3, 4) making the anastomosis are shown (B) Diagrammatic cross section through the vas showing the depth of the anastomotic suture in its wall. (C) The oval fenestra has been cut in the globus major, the needle carrying the fistula wires from the vas has been partially passed through the globus major. (D) The anastomosis between the vas deferens and epididymis has been completed The three wires which temporarily maintain the fistula are shown, their course is indicated by the dotted line. The four anastomotic suture wires have been passed and tied Three of them have not been cut and are shown. (D) The operative wound in the scrotum has been closed The ends of the group of three fistula-maintaining sutures have been brought out through the scrotal skin and are held in place by shot

(Michelson, L: Vaso Epididymal Anastomosis. *Surg Gylnec. & Obst*, 82 327, 1946)

couple should not be denied this attempt at surgical correction if they wish it, even if the consultant feels that it is hopeless. The satisfactory results in the literature vary from 20 to 33 per cent, but almost all patients on whom it has been done and failed feel satisfied that they have tried everything to relieve their infertility before resorting to artificial insemination or adoption. In the author's last 25 cases, 8 were obviously hopeless on exploration as patency of the vas above the proposed site of anastomosis could not be demonstrated. The individuals lost only 48 hours from their occupation and considered the attempt well worth while. Eight patients had apparent patency of the vas by irrigation with methylene blue above the site of the proposed anastomosis. The anastomosis was carried out, but no spermatozoa have ever been found subsequently. Two of these patients were reoperated without favorable results. One of the latter, with the second operation, had stainless steel wires, according to the technic of Michelson, without satisfactory results Nine patients have been found to have sperm in the seminal fluid following epididymovasostomy bilaterally. The first successful patient had no sperm before operation, and 71,000,000 sperm per cubic centimeter, postoperatively, but he and his wife were divorced before an attempt at pregnancy could be initiated. Three other patients had definite live sperm in the seminal fluid after operation for a period of three to six months, then the spermatozoa disappeared again, indicating that the obstruction had recurred, probably at the site of anastomosis. Five patients remain whose tubes are still patent and continue to show living spermatozoa. One who has now gone to a foreign country is reported to still have sperm although his wife has not become pregnant. Details of the investigation of her condition are not known. One, in another foreign country, has reported the presence of sperm on three occasions, and his wife has been delivered of a normal child. A third patient's wife is also now pregnant. In one case where bilateral obstruction was relieved by irrigation of the vasa, 2 children have resulted without anastomosis. The conclusion is that the patient with azoospermia due to obstruction should be offered the appropriate surgical therapy, and if he so elects should be allowed the opportunity for a surgical relief of this problem. As the technic improves and the condition is recognized earlier, particularly with the aid of chemotherapy and possibly hormonal effects on improving the lumen of the vas, a higher incidence of favorable results may be obtained.

. One or two
anastomosis.

"The lower ends of the fistula-producing wires which have been threaded on a skin needle are passed through the tunica vaginalis and the skin of the scrotum about 2 0 cm. below the end of the incision in the scrotum Similarly the upper ends of these wires are passed about 2 0 cm above the upper end of the scrotal incision The tunica vaginalis is sutured with catgut after first the introduction of an exploring finger to make sure that the organs are in proper position The incision is closed with deep mattress sutures of silkworm gut and the skin with a running catgut suture Before the incision is closed, it is advisable to measure on the wires where the shot should be applied so that there will be no tension. Following the closure of the skin incision both the upper and the lower ends of the wires are shotted separately Tincture of benzoin compound, gauze, and a large-sized suspensory are applied with plenty of gauze for pressure

"The fistula wires are removed in 10 to 14 days without any difficulty. Convalescence in all cases has been uneventful." (From *Surg., Gynec. & Obst*, 82.327, 1946)

MALDESCENT OF THE TESTES

Failure of descent of one or both testes should be recognized, preferably prepuberally, but if treatment is postponed until the onset of puberty, it should be brief and definitive and consist of various forms of orchiopexy. MacCollum has shown that 61 per cent of men who had the operation carried out before puberty have since become parents, while none of the cases that had the operation done after puberty became parents. There is urgent need for the pediatrician and physician who see children and prepuberal boys to determine whether or not the testes seem to be normal in growth. In passing, it is our feeling that an undescended testis should be removed after the patient reaches 21 years of age because of the possibility of malignancy It is hoped that hormonal studies may be done on a number of such cases before and after such surgery, in order to determine whether the removal of the undescended testis which is definitely not making sperm may improve the function of the descended testis in men with oligospermia.

VARICOCELE

It is doubtful if small or medium-sized varicoceles are important in the cause of male infertility. However, large varicoceles are probably a factor in cases where the wife was normal and the sperm picture looked essentially normal. Excision of the varicocele by the usual measures or the popular ligation of the internal spermatic vein through an inguinal incision, coupled with testicular biopsy, should be offered those men who have this complaint, even in the absence of symptoms directly from the varicocele One couple was referred for artificial insemination because the husband had less than 1,000,000 sperm per cubic centimeter. Operation was recommended and carried out in March after confirmation of the severe oligospermia and the following August the wife became pregnant, at which time one sperm count revealed 52,000,000 sperm per cubic centimeter In the last 7 cases of varicocelectomy for oligospermia, 5 have shown moderate to marked improvement in spermatogenesis. The result may be delayed and it may be over a year before the poor spermatogenesis has shown definite improvement

PROSTATIC MASSAGE

Probably not enough importance has been attributed to the benefits to be obtained by regularly instituted massage of the prostate gland. Most authors mention it usually in passing but few have emphasized its value. To be worth while it must be performed every seven to 10 days until the secretion contains less than 10 to 15 white blood cells per high powered field or until the urine voided after massage becomes free from shreds or plaques of mucus. It has often been noted that men with waning sexual potency, loss of libido, or chronic fatigue respond favorably to the periodic emptying of this structure by massage. Usually the first two or three treatments are painful or uncomfortable. The patient and the doctor tend to avoid repeating this unpleasant experience. Since results are not immediately realized, *laissez faire* is a natural policy to follow. If the physician persists in getting the male back for regular treatment and insists on accompanying

measures of moderation in living on the patient's part, improvement may be expected. Moderation means avoiding alcohol, coffee, spices, excessive coitus, and all manner of fatigue.

Massage should be carried out on a full bladder and it is our practice to advise the patient to drink two tumblers of water before leaving to come to the office and not to void until after his treatment. Therapy should last a minute or two and start gently. It can be increased in intensity from time to time until real pressure does not elicit pain. If accompanied by supportive measures it is evident that the prostatic fluid becomes a much more suitable vehicle and nutrient for the spermatozoa. A course of treatment usually lasts six to eight weeks. Instead of discontinuing the treatment then, follow-up massage at four to five week intervals will maintain the benefits instituted by more frequent treatment.

ARTIFICIAL INSEMINATION

While artificial insemination does not properly come under the heading of the treatment of male infertility, it should be commented on briefly because of its solution of relief of the infertility of the couple when the wife's examination is within normal limits of fertility, and the husband's demonstrates *irremediable* sterility. The more than 9,000 successful pregnancies, in necessarily anonymous couples, are adequate proof of its acceptance when indicated. Those doctors offering this simple relief of an otherwise insoluble problem are unable publicly to testify to the extreme satisfaction of those couples so treated. Anyone doing this work can, however, state that the majority of couples promptly return for a second pregnancy following the successful termination of the first.

Follow-up studies on many such couples indicate that there are no problems of serious import on the part of either partner of these marriages, and the living proof of the highly desirable physical results of such pregnancies makes the technic one which should be available to any suitable couple when the problem is present

Artificial insemination using the husband's specimen is a form of therapy *markedly abused by those who do not know its indications. It is to be used only* where the husband has normal semen which he is incapable of depositing in the wife's cervical mucus at the appropriate time in the cycle. It is not practical, or successful, to take a deficient sperm sample and expect it to inseminate the wife if the husband can deposit those same sperm in the cervical mucus. In rare instances, cervical hostility or poor motility on the part of the sperm makes it advisable to carry out this procedure by washing the semen in Ringer-Locke solution, and concentrating it to an increased density by the centrifuge. This specimen is then introduced into the cervical mucus under direct vision, but in no instances should it be passed beyond the level of the internal os of the uterus. The procedure is hazardous, and results frequently in sterilizing infection of the uterine cavity or fallopian tubes. Its use should be restricted to those who have had experience with artificial insemination with a heterologous specimen, and a reasonable degree of surgical asepsis.

CONCLUSIONS

It should be apparent, then, that the *investigation of the barren couple* is *grossly inadequate* without the study of both. For our present purposes emphasis on the male is more logical, less costly, less dangerous, and definitely indicated with the increasing incidence of male infertility. The important thing is completeness of the history, physical, laboratory, and therapeutic approach. These require the proper training of the physician, his interest in the patient and the problem, and his realization that his obligation to the couple is to eliminate improper treatment and delay in treatment. His aim should be to encourage better adolescent hygiene and the control of venereal and other infections. Nicholas J. Eastman, Chairman of the Editorial Committee of the National Committee on Maternal Health has said "the discovery that male sterility is widespread, and a frequent cause of sterile wedlock, has opened up a new province in urology, one that is rich from both the research and clinical viewpoints."

REFERENCES

Belding, D. L.: Fertility in Male, Technic of Spermatozoa Count. *Am. J. Obst. & Gynec.*, 27:25, 1934

Belding, D. L.: Fertility in Male; Technical Problems in Establishing Standards of Fertility. *Am J. Obst & Gynec.*, 26:868, 1933

Blom, E.: Semen Stain. *Am. J Fertility and Sterility*, No 3, 1950.

Cary, W. H.: *Examination of Semen with Special Reference to Its Gynecological Aspects. Am J. Obst & Gynec.*, 74:615, 1916.

Cary, W. H.: Discussion of J K. Lamar's paper, "Some Observations on Sperm Migration Through Cervical Mucus," Conference on Problems of Human Fertility (Edited by E. T. Engle), National Committee on Maternal Health. Menasha, Wis: George Banta Publishing Co., 1943.

Cary, W. H., and Hotchkiss, R. S.: Semen Appraisal; A Differential Stain That Advances the Study of Cell Morphology. *J A M.A.*, 102:587, 1934.

Charny, C. W.: The Testicular Biopsy. A Five-Year Survey, *Proceedings of Conference on* Diagnosis in Sterility (Edited by E. T. Engle), Springfield, Ill.: C. C. Thomas, 1946.

Charny, C W.: Testicular Biopsy; Its Value in Male Sterility. *J.A M A.*, 115:1429, 1940.

Charny, C W., and Meranze, D. R.: Testicular Biopsy, Further Studies in Male Infertility. *Surg., Gynec & Obst.*, 74:836, 1942

Corner, G W: *The Hormones in Human Reproduction* Princeton: Princeton University Press, 1942

Davis, C D., et al. Therapy of Seminal Inadequacy; Use of Extract of Chorionic Gonadotropin and "Pituitary Synergist." *J. Clin Endocrinol.*, 3:357, 1943.

Davis, C D, et al: Therapy of Seminal Inadequacy; Use of Pituitary, Chorionic and Equine *Gonadotropins J Clin Endocrinol*, 3:268, 1943.

Dickinson, R L. *Human Sex Anatomy.* Baltimore Williams & Wilkins Company, Ed. 1, 1933, Ed 2, 1949.

Engle, E. T. (Editor). The Problem of Fertility, *Proceedings of Conference on Fertility Held Under the Auspices of the National Committee on Maternal Health.* Princeton, New Jersey Princeton University Press, 1946.

Farris, E. J: Improved Method for Semen Analysis. *J. Urol*, 58:85, 1947

Greenhill, J. P. (Editor): Infertility, Editor's note on page 303. *The 1948 Year Book of Obstetrics and Gynecology.* Chicago: The Year Book Publishers, Inc., 1948.

Haggart, W. D.: *Reference Handbook of Medical Science.* New York: William Wood & Co., 1904

Hamblen, E. C.: *Facts for Childless Couples.* Springfield, Ill.: C. C. Thomas, 1942, 1946.

Hamblen, E. C. *Endocrine Gynecology*. Springfield, Ill.: C. C. Thomas, 1939, 1945.
Heckel, N. J.: Production of Oligospermia in Man by Use of Testosterone Propionate. *Proc. Soc. Exper. Biol. & Med.*, *40*:658, 1939
Heckel, N. J., and Steinmetz, C. R.: Effect of Testosterone-Propionate upon Seminal Fluid in Man. *J. Urol.*, *45*:118, 1941
Heller, C. G., and Maddock, W. O. Use of Androgens in Men. *Bull. New York Acad. Med.*, *24*:179, 1948.
Heller, C. G., and Nelson, W. O.: Hyalinization of Seminiferous Tubules Associated with Normal or Failing Leydig-cell Function, Discussion of Relationship to Eunuchoidism, Gynecomastia, Elevated Gonadotrophins, Depressed 17-Ketosteroids and Estrogens. *J. Clin. Endocrinol.*, *5*:1, 1945
Heller, C. G., and Nelson, W. O.: Hyalinization of Seminiferous Tubules and Clumping of Leydig-Cells, Notes on Treatment of Clinical Syndrome with Testosterone Propionate, Methyl Testosterone and Test-osterone Pellets. *J. Clin. Endocrinol.*, *5*:27, 1945.
Hinglais, H., and Hinglais, M.: Contribution à l'étude et à l'appréciation de la valeur fécondante du sperme humain, étude comparative du sperme de 504 hommes appartenant à des ménages stériles et de 27 hommes de fécondité prouvée. *Semaine d. hôp. Paris*, *23*:2490, 1947.
Hotchkiss, R. S. *Fertility in Men, a Clinical Study of the Causes, Diagnosis, and Treatment of Impaired Fertility in Men*. Philadelphia: J. B. Lippincott Co., 1944.
Hotchkiss, R. S., Brunner, E. K., and Grenley, P.: Semen Analyses of 200 Fertile Men. *Am. J. M. Sc.*, *196*:362, 1938
Howard, R. P., et al. Testicular Deficiency, A Clinical and Pathological Study. *J. Clin. Endocrinol.* To be published in 1950
Huhner, M.: *The Diagnosis and Treatment of Sexual Disorders in the Male and Female, Including Sterility and Impotence*. Philadelphia: F. A. Davis, Ed. 1, 1937; Ed. 2, 1939
Huhner, M. *Sterility in the Male and Female*. New York: Rebman Company, 1913.
Jungck, E. C., et al. Blood Vitamins A, C, and E and Seminal Fluid Vitamin C in Human Male Sterility. *Federation Proc.*, *6*:139, 1947
Klinefelter, H. F., Jr., Reifenstein, E. C., Jr., and Albright, F.: Syndrome Characterized by Gynecomastia, Aspermatogenesis without A-leydigism, and Increased Excretion of Follicle-stimulating Hormone. *J. Clin. Endocrinol.*, *2*:615, 1942.
Kurzrok, R., Leonard, S. L., and Conrad, H.: Role of Hyaluronidase in Human Infertility. *Am. J. Med.*, *1*:491, 1946.
Lamar, J. K., Shettles, L. B., and Delfs, E.: Cyclic Penetrability of Human Cervical Mucus to Spermatozoa in Vitro. *Am. J. Physiol.*, *129*:234, 1940.
Lane-Roberts, C. S., et al.: *Sterility and Impaired Fertility, Pathogenesis, Diagnosis and Treatment*. London: H. Hamilton, 1948.
MacCollum, D. W. Clinical Study of Spermatogenesis of Undescended Testicles. *Arch. Surg.*, *31*:290, 1935
Macomber, D., and Saunders, M. B.: The Spermatozoa Count; Its Value in Diagnosis, Prognosis, and Treatment of Sterility. *New England J. Med.*, *200*:981, 1929.
MacLeod, J. Male Factor in Fertility & Infertility. *J. Fertility & Sterility*, *XI*. No. 4, 1950
MacLeod, J. The Semen Specimen: Laboratory Examination. *Proc. Conference on Diagnosis and Sterility* (Edited by E. T. Engle), Springfield, Ill.: C. C. Thomas, 1945.
MacLeod, J., and Hotchkiss, R. S. Effect of Hyperpyrexia Upon Spermatozoa Counts in Men. *Endocrinology*, *28*:780, 1941
McLane, C. M. Infertility and Sterility, 6-Year Study. *Journal-Lancet*, *64*:340, 1944
Meaker, S. R. Relations Between Depressed Respiratory Metabolism and Low Fertility. *J. Mt. Sinai Hosp.*, *14*:496, 1947
Meaker, S. R.: *Human Sterility, Causation, Diagnosis and Treatment, a Practical Manual of Clinical Procedure*. Baltimore: Williams & Wilkins Co., 1934.
Meigs, J. V., and Sturgis, S. H. *Progress of Gynecology*. New York, Grune & Stratton, 1946
Michelson, L.: Treatment of Azoospermia by Vaso-epididymal Anastomosis. *West. J. Surg.*, *55*:120, 1947

Michelson, L.: Vaso-epididymal Anastomosis by Production of Permanent Fistula with Use of Stainless Steel Wire. *Surg., Gynec., & Obst.*, 82:327, 1946.

Moore, C. R.: Biology of the Testes, in: *Sex and Internal Secretions* (Edited by E. V. Allen). Baltimore: Williams & Wilkins Co., 1939.

Moricard, R.: Comparative Physiology of Fecundation and Applications to Study of Human Sterility. *Am. J. Gynec. & Obst.*, 47:411, 1948.

Phillips, R. W., and McKenzie, F. F.: The Thermo-regulatory Function and Mechanism of the Scrotum, in *Missouri Agricul. Experiment Sta. Res. Bull.* No. 217, Columbia, 1934.

Nelson, W. O., and Heller C. G.: Hyalinization of Seminiferous Tubules Associated with Normal or Failing Leydig-Cell Function; Microscopic Picture in Testis and Associated Changes in Breast. *J. Clin. Endocrinol.*, 5:13, 1945.

Pollak, O. J.: Semen and Seminal Stains, Review of Methods Used in Medicolegal Investigations. *Arch. Path.*, 35:140, 1943.

Pommerenke, W. T., and Viergiver, E.: Comparison of Rates of Penetration of Unwashed and Washed Spermatozoa in Cervical Mucus. *Proc. Soc. Exper. Biol. & Med.*, 66:161, 1947.

Rock, J. C.: Investigation and Treatment of Infertility. *Med Clin. North America*, 32:1171, 1948

Rock, J. C., and Loth, D. G.: *Voluntary Parenthood.* New York. Random House, 1949.

Salmon, U. J., and Frank, R. T.: Hormonal Factors Affecting Vaginal Smears in Castrates after Menopause. *Proc Soc. Exper. Biol. & Med*, 33.612, 1936.

Scott, W. W.: Modern Laboratory Technics in Urology, in *Monographs on Surgery* (Edited by B Noland Carter), New York: Thomas Nelson & Sons, 1950.

Shettles, L. B.: *The Relation of Nutrition to Spermatogenesis. Conference on Biology of Spermatozoa, Proceedings March 21-22*, New York City, 1942.

Siegler, S. L.: *Fertility in Women.* Philadelphia: J. B. Lippincott Co., 1944.

Simmons, F. A: The Treatment of Male Infertility. Proc Amer. Therapeutic Soc. 1949, Fertility & Sterility, I: No 3, 1950

Simmons, F. A: Clinical Interpretation of the Semen Analysis. *Conference on Diagnosis in Sterility, Proceedings* (E T Engle, Editor), Springfield, Ill.: C. C. Thomas, 1945.

Simmons, F. A.: Diagnostic Technics and Treatment of the Sterile Couple. In Meigs and Sturgis' *Progress in Gynecology*, pp 246-253, New York: Grune & Stratton, 1950.

Simmons, F. A.: The Cervix Uteri in Infertile Matings. *Conference on Fertility Proceedings*, (E T. Engle, Editor) Princeton. Princeton University Press, 1946.

Simmons, F. A Sterility in Male and Female. *Bull. New England M. Center*, 4:75, 1942.

Simmons, F. A, and Shiffen, R. Testicular Biopsy in Sterile Male *West. J. Surg.*, 55.508, 1947.

Sims, J. M · *Clinical Notes on Uterine Surgery* New York: William Wood & Co., 1886.

Sniffen, R. C, Howard, R. P., Simmons, F. A.. The Testes· Abnormalities of Spermatogenesis. Atresia of the Excretory Ducts, *Arch. Path.*, 50 285, 1950.

Weisman, A I *Spermatozoa and Sterility; A Clinical Manual.* New York. P. B. Hoeber, Inc, 1941.

Weisman, A I *You Too Can Have a Baby* New York: Lavenght Publishing Co, 1941.

Williams, W W. Male Sterility.-*Connecticut M. J.*, 7:538, 1943.

Williams, W W, McGugan, A, and Carpenter, H. D.: Staining and Morphology of Human Spermatozoon *J Urol*, 32 201, 1934

Williams, W W, and Simmons, F. A.: Clinical Approach to Diagnosis of Sterility. *Urol. & Cutan Rev*, 46 558, 1942.

The Surgical Management of Prostatic Disease

STANLEY H. MOULTON, M.D. AND CHARLES HUGGINS, M.D.

ETIOLOGY OF BENIGN PROSTATIC HYPERTROPHY

THE MODERN SURGICAL management of prostatic disease implies a knowledge of the anatomic and physiologic variations which occur in the human prostate in the aging male. While most anatomic structures atrophy with senescence the prostate gland commonly enlarges, owing to a glandular or fibromuscular hypertrophy. Benign prostatic hypertrophy is a result of aging. While some authors report an occasional case of prostatic hypertrophy between the ages of 30 and 39, it is characteristically a disease of men over 40, and 75 to 80 per cent of all men over 80 have benign prostatic hypertrophy.

Grossly and histologically there is no clear division of the prostate gland into lobes. Lowsley has shown by embryologic studies that five distinct groups of tubules develop from five separately situated points of origin in the floor of the prostatic urethra; however, it is incorrect to assume that these groups of tubules develop subsequently into five prostatic lobes. In the modern view of benign prostatic hypertrophy, the apparent formation of "lobes" is regarded as asymmetric development of the spheroids. There is a distinct capsular separation of the posterior segment from the rest of the prostate. The posterior region arises from the urethral floor independently of the anterior segment and this fact is evidence for the anatomic duality of the prostate (Fig. 1).

In recent years a clearer understanding of the etiology of benign prostatic hypertrophy has been gained. Although the lesion appears grossly smooth, it is not a hypertrophy but consists of multiple nodules composed of three elements: epithelium, smooth muscle, and fibroblasts (Fig. 1) It is apparent that the multiplicity of the nodules is an indication of multiple centers of origin of the pathologic process. As demonstrated by biochemical studies, the epithelium of the prostatic adenoma is physiologically active. Incompletely removed spheroidal nodules usually regenerate. This phenomenon explains the high incidence of recurrent operation for obstruction following transurethral resection on large lesions (Fig. 2).

The site of origin of benign prostatic hypertrophy is well understood, being in the prostatic acini All of the data indicate with certainty that only the medullary portion of the prostate is involved by benign prostatic hypertrophy. It has been shown that cancer of the prostate usually arises in the cortical portion of the prostate (Fig. 1).

The most fruitful methods by far in elaborating the mechanism of prostatic hypertrophy have been endocrinologic studies. In benign prostatic hypertrophy the prostatic epithelium consists of tall columnar cells. It has been shown in

animals that castration causes a decrease in the height of this cell which is readily restored by androgen. In man orchiectomy is followed by a decrease in cellular height and epithelial atrophy of the benign prostatic hypertrophy. Clinically a decrease in the size of the gland and relief of obstructive symptoms have been noted. Estrogen administered to man produces changes of the acini of the medullary prostate and its spheroidal nodules, in contrast to the unchanged normal epithelial cells of the cortical prostate; however, atrophy is slow in developing



FIG. 1.—Demarcation of the anterior and posterior segments of the prostate is indicated by the arrows. There are benign spheroidal tumors in the anterior segment and a carcinoma in the posterior segment.

man consists of neoplastic nodules
te as the result of a testicular stim-
a long period of years on a tissue
which at that time has developed with senescence a low threshold to androgens.

The phenomena of the epithelium of cortical prostate differing from the epithelium of benign prostatic hypertrophy in its response to estrogen, the embryologic development of the prostate in man, and the propensity in man for the cortical and medullary prostate to form different neoplasms demonstrate that the human prostate gland is composed of two different types of tissue (Fig. 1).

Benign prostatic hypertrophy is not the only etiologic factor in obstructive uropathy. Carcinoma of the prostate may involve the vesical neck and cause obstruction. Chronic inflammation with resultant fibrosis may produce a true contracture of the vesical neck and obstruction, and the median bar, consisting of a dam of dense sclerotic tissue stretched across the posterior lip of the vesical orifice, may produce urethral obstruction.



Fig. 2.—Nod ... was obtained
by perineal ... ra, note the

TRANSURETHRAL RESECTION

Prostatism was not recognized as a disease entity until about 1800 and surgical methods of relieving prostatism before the advent of open prostatic surgery depended on the urethral route Early transurethral methods of relieving prostatic obstructions by using lithotrites with one blade modified as a cutting tool were developed between 1840 and 1880 by the French surgeons, Civiale, D'Etoilles, and Mercier. This method soon fell into disuse, for all that could be accomplished with these instruments was incision of the vesical neck and the results were usually poor In 1877 Bottini demonstrated his galvanocautery incisor which was a lithotrite-like instrument with the moving cutting blade replaced by a platinum blade insulated and connected to a source of electrical energy by insulated wires. There was no lens system and the instrument operated by producing tissue destruction and slough at the site of the obstruction. By 1900 the transurethral route for relieving prostatic obstruction was largely discarded in both Europe and America as open surgical approaches for the relief of prostatism began to find favor Beginning in 1926 the modern resectoscope began to evolve, using three basic developments, the high frequency current, the incandescent lamp, and the fenestrated sheath

The evolution of the American cystoscope was a result of the efforts of Hugh H. Young, Leo Buerger, Tildon Brown, William F. Braasch, Joseph F. McCarthy, and Bransford Lewis. The technic of relieving urinary obstruction by transurethral surgery confined itself originally to the median bar type of obstruction. In 1909 Hugh H Young devised his punch instrument, a tubular sheath with a

fenestra and a tubular knife fitting inside to cut any obstructing tissue that could be engaged in the fenestra. Braasch modified this nonvisual instrument by combining his direct vision cystoscope to include the features of the fenestra and cutting punch so that excellent vision was obtained.

In 1926 Bumpus modified this instrument by the use of a tubular knife and a flexible electrode to control hemorrhage. Also in 1926, Stern replaced the tubular cutting tool with a tungsten wire loop using high frequency undamped current. In 1931, T M. Davis announced his results with the modified Stern resectoscope in which he had improved the cutting currents. Finally, in 1932 McCarthy demonstrated the resectoscope consisting of a foroblique lens system and a bakelite sheath with a tungsten cutting loop. This is essentially the instrument used today for prostatic electroresection. The other fundamental type of instrument used today was developed from Young's punch system and improved by Tolson when he added the foroblique lens and improved the cutting efficiency of the instrument by changing the shape of the blade. G. J. Thompson further improved the instrument by modifying its design. Thompson and his co-workers who now use this instrument find that the cold punch has many advantages and use this instrument to excise large amounts of tissue.

In this country transurethral resection is the most popular method of relieving urinary obstruction. Of the four accepted methods of removing obstructive tissue there are more transurethral resections done than the other three methods combined Statistical comparisons indicate that transurethral resection is followed by a lower mortality and a shorter hospital stay than other methods.

There is some difference of opinion regarding the indications for transurethral resection and recent reports indicate that many resectionists are becoming more conservative in their use of this method. Until the last few years most resectionists believed that in the hands of a competent experienced operator even large glands could be adequately removed and that about 75 per cent of obstructive prostates could be handled by transurethral resection. In recent years, however, it has been generally accepted that to avoid recurrent operations and persistent infections, a transurethral resection should remove not only obstructing urethral tissue but all adenomatous tissue down to the prostatic capsule. Many urologists are accordingly revising their indications for choosing the transurethral method and resect no glands which are more than moderately enlarged. There is complete agreement, however, that the method is ideally adapted to relieving urinary obstruction caused by median bars, small fibrous glands, contractures of the vesical neck, median lobe enlargement, and small to moderate lateral lobe adenomatous enlargement which is not subtrigonal. With the exception of relieving obstruction caused by moderate enlargement of the lateral lobes, the suprapubic, perineal, and retropubic methods give consistently inferior results in the above categories of urinary obstruction

Transurethral resection is also generally considered the method of choice in relieving obstruction caused by inoperable cancer of the prostate which has not responded to estrogen therapy or orchiectomy and for poor risk patients who are unable to stand open surgery, even though multiple operations may be required in each instance.

There are certain distinct disadvantages to this method. Technically it is diffi-

cult to learn and to use, because of its indirect approach and small tolerances between tissue which must be resected and tissue resection of which will result in disaster. The cutting loop may open the bladder extraperitoneally, permitting extravasation of irrigating fluid with resultant cellulitis or abscess, depending on the extent and nature of the extravasation. An error of only a few millimeters in resecting adenomatous tissue adjacent to the external sphincter may damage the sphincter either partially or cut it completely, resulting in a temporary or permanent urinary incontinence, but the incomplete removal of only a few millimeters of tissue at this site may not relieve the obstruction.

The incidence of postoperative stricture of the urethra from the trauma of passing the resectoscope is also appreciable and such strictures may necessitate years of postoperative urethral dilatation.

Hemorrhage during operation may be profuse and difficult to control, often necessitating immediate discontinuance of the operation and reoperation at a later date. In some instances shock may occur either during or within hours of the operation.

Hemoglobinuria and hemoglobinemia may occur during operation with the resultant serious complications of oliguria, anuria, and uremia. Creevy has demonstrated that by using sterile isotonic nonelectrolytic irrigating solutions such as glucose rather than the usual hypotonic sterile tap or distilled water, intravascular hemolysis caused by the irrigating fluid entering open veins in the resected prostate can be prevented

Postoperative complications of secondary hemorrhage resulting from slough and infection about eight to 14 days after operation are occasionally encountered and may be severe

Inadequate resection with incomplete removal of the prostate frequently occurs. The completeness of removal of all adenomatous prostatic tissue varies directly with the experience of the resectionist and perforce many resections will be inadequate. However, when large glands are resected, the incidence of recurrent operations is high for even the experienced operator and has caused this operative route to be contraindicated for large glandular hypertrophies.

Sexual function is not commonly altered following transurethral resection but occasionally does occur, and since the resection is most often used for the type of obstruction encountered in the younger age group, this complication can be serious.

Shivers and Groom, in an analysis of 14,865 cases of prostatectomy collected by a questionnaire from 1,200 members of the American Urological Association, report an over-all mortality rate of 3.0 per cent from all operations. They report the following data for transurethral resections:

	Mortality Per Cent	*Prolonged Morbidity Per Cent*	*Persistent Obstruction Per Cent*	*Persistent Infection Per Cent*	*Persistent Residual Per Cent*	*Incontinence Per Cent*
6782 single resections	2 2	8 4	6 5	7.1	3 1	0.9
1726 multiple resections	2.5	10.9	15.9	9 8	6.9	1.2

At the University of Chicago Clinics of 300 recent consecutive prostatectomies there were 5 deaths (1.66 per cent mortality) (Table I). Of the 300 cases, 84

were done by the transurethral route with 1 death (mortality 1.19 per cent), 2 persistent cases of incontinence, and 5 cases of persistent stricture.

PERINEAL PROSTATECTOMY

The first prostatectomies were done through the perineum. In the Middle Ages patients were operated for stone by a median or lateral perineal incision and occasionally a portion of the hypertrophied prostate was removed with the stone in an attempt to relieve obstruction. The procedure then fell into disuse until, in 1848, Sir William Ferguson occasionally removed a prostate while removing a stone by perineal surgery. T. Billroth, however, did the first intentional prostatectomy not associated with calculus in 1867 and later, in America, Goodfellow did a series of perineal prostatectomies.

Hugh H Young, after considerable experience with prostatic cauterization and suprapubic enucleation, was disappointed with these methods and in 1902, after long study and dissection of the perineum, did his first perineal prostatectomy. He developed and perfected the surgical approach to the prostate via the perineum and designed and developed special instruments to facilitate the method. It was through his efforts and teaching that the perineal approach to the prostate became accepted in this country. Since his perfection of the procedure both technic and instruments have undergone modifications which have developed the operation to the high degree of specificity where it stands today.

In 1939 Belt, Ebert, and Surber described a new perineal approach to the prostate in which use is made of the cleavage plane between the external longitudinal fibers of the rectum and the external sphincter ani muscle. By using this route the prostatic capsule can be exposed bloodlessly and without cutting nerves.

Perineal prostatectomy, as is evident from statistics, is a comparatively little used method. There are few men in this country who use it in preference to other methods. Its lack of popularity is generally considered to be due to the individual surgeon's lack of precise knowledge of the anatomy of the male perineum. In many large hospitals it is a rarely used approach. Of the 14,865 cases reported by Shivers and Groom in 1948 only 493 (3.4 per cent) of the cases were operated on by the perineal route.

There are disadvantages which are peculiar to the perineal route aside from its being difficult to master. The method carries with it a greater risk of rectal injury with urethrorectal fistula than do other methods. There is also a higher incidence of incontinence and impotence accompanying this procedure than is found following the suprapubic, transurethral, or retropubic approach. If there are intravesical lesions which should be treated simultaneously with prostatectomy, the perineal route is contraindicated Deformities or ankylosis of hip joints and spine and leg fractures may make it inadvisable to put the patient into the absolutely essential position of extreme flexion of the thighs on the trunk. Because of the necessity of this exaggerated position in the performance of the operation, the operation is contraindicated in certain cardiac and respiratory conditions.

In spite of these hazards the perineal approach is considered by those trained in its use to be the most ideally adapted route to the prostate. It is the most direct surgical approach, for the prostate can be exposed through a small perineal

incision. Vital functions of abdominal organs are undisturbed and accordingly poor risk patients tolerate perineal prostatectomy better than any other procedure for permanent relief of urinary obstruction. To quote Hugh Young: "The great advantage of the operation is that it is performed under the complete visual control of the operator; that hemorrhage encountered is stopped; the enucleation is certain in its completeness; the verumontanum, ejaculatory ducts, internal and external sphincters are protected; dependent drainage for urinary inflammatory secretions is obtained; and the lowest mortality rate is secured."

The greatly hypertrophied glands or those enlarged posteriorly may be difficult with any other method but are easiest by the perineal route. In the obese patient the method has obvious advantages over the suprapubic operation. Prostatic calculi, prostatic abscess, and suppurative prostatitis are ideally managed perineally because of ease of accessibility and dependent extravesical drainage. When there is suspicion of carcinoma of the prostate unconfirmable by nonoperative technics, the perineal route is indicated. It is by this route that biopsy of the posterior lobe with frozen section may be most easily and quickly effected and in the event of positive diagnoses of carcinoma a total perineal prostatectomy thus done gives the patient his only chance of a cure.

As to the hazards of the method, rectal injury and incontinence may be prevented by assiduous attention to anatomic detail and cautious use of prostatic retractors. In the hands of properly trained surgeons the incidence of these complications decreases as the operator gains experience with the method. Impotence, although a common sequel of perineal prostatectomy, is accepted with little or no complaint by most patients. Because of their age and general condition they are rarely sexually ambitious and this complication is not to be considered a hazard in most cases. Shivers and Groom in their reported series of 14,865 prostatectomies indicate that 493 were done by the perineal route, with a mortality of 3 9 per cent, 0.9 per cent higher than the over-all mortality for all methods. They give the following data on incidence of complications:

Prolonged Morbidity	*Persistent Obstruction*	*Persistent Urinary Infection*	*Persistent Residual*	*Persistent Fistula*	*Incontinence*
5 9 per cent	0 6 per cent	3.0 per cent	0 6 per cent	5 5 per cent	2.4 per cent

Of the series of 300 consecutive prostatectomies done at the University of Chicago Clinics, 23 cases were done by the perineal route with 2 deaths (8.7 per cent mortality), 3 cases had a slight incontinence, no persistent fistulas developed, and no cases of urethral stricture occurred. Nine total perineal prostatectomies were done with no deaths.

SUPRAPUBIC PROSTATECTOMY

Suprapubic prostatectomy was at one time in poor favor as a method for the relief of prostatic obstruction because of the accompanying high incidence of morbidity and mortality, but in recent years it has gained the respect due its distinct advantages It has evolved through many changes in preoperative and postoperative care and the technic has been perfected until at present its mortality and morbidity rates compare favorably with those of other methods. Previously

done as a two-stage procedure or following suprapubic drainage, the use of antibiotics and improved supportive care now make it possible to do this operation in one stage. Morbidity and mortality from hemorrhage have become markedly reduced because bleeding from the prostatic fossa can now be better controlled with perfected hemostatic catheters, and the use of hemostatic absorbable gauze, fibrin, and gelatin foam together with the increased use of blood transfusions. Because it is far easier to learn and perform than transurethral perineal or retropubic prostatectomy, its popularity will undoubtedly continue.

The advantages of the method aside from its simplicity are that it is followed by less disturbance of sphincter control and sexual function than the transurethral, perineal, or retropubic route and it is performed with complete immunity from rectal damage

Vesical diverticula, calculi, and neoplasm may be treated simultaneously with the prostatic enucleation. Large intravesical or subtrigonal hypertrophy or the encroachment of an excessively large gland on a ureter is ideally handled by the suprapubic route which provides the surgeon with good exposure and direct visualization.

The disadvantages of the suprapubic prostatectomy are its slightly higher incidences of mortality and morbidity, presumably because it is a transvesical and transabdominal approach with greater perivascular trauma and the opening of more cleavage planes Low lying prostatic hypertrophies can be technically difficult to enucleate by the suprapubic route, as may be the adenomas of extremely obese individuals. Poor risk patients with cardiac or respiratory disease are generally handled with less mortality by one of the other methods. Urethral stricture and vesical neck obstruction have an appreciable incidence following suprapubic enucleation. However, when attention is paid to effecting the complete removal of all small neoplastic nodules which adhere to the capsule, to tags of muscle at the vesical neck, and to bars or folds of tissue at the floor of the vesical orifice without tearing the membranous urethra, the incidence of these complications is greatly decreased

Small fibrous glands, true median bars without excessive glandular hypertrophy, and vesical neck contractures are handled more precisely by the transurethral route. When rectal examination raises a suspicion of carcinoma of the prostate unconfirmed by roentgenographic or phosphatase studies, the suprapubic route is contraindicated in favor of the perineal approach and posterior lobe biopsy. Following suprapubic prostatectomy the patient is not as comfortable as are those postoperative patients on whom other methods have been used. The hospital stay is longer, the patient frequently has severe bladder neck spasms for the first day or two, and, following the removal of the suprapubic mushroom catheter, which is usually employed, there is urinary drainage from the suprapubic sinus for several days.

At the University of Chicago Clinics of 300 consecutive cases of prostatectomy, 173 were done by the suprapubic route with 2 deaths (1.16 per cent mortality). The over-all mortality was 5 deaths (1.66 per cent). Following removal of the suprapubic mushroom catheter the average time for closure of the suprapubic sinus was four days. Three patients had persistent suprapubic fistulas which finally closed in less than 20 days. There were 7 cases of postoperative urethral

stricture requiring dilatation (4 per cent) but only 2 of these patients required dilatation longer than six months. There were 4 cases of persistent incontinence (2.3 per cent) and 1 case of osteitis pubis

Shivers and Groom report the following data from the 14,865 cases they collected:

	Mortality Per Cent	Morbidity Per Cent	Persistent Obstruction Per Cent	Persistent Urinary Infection Per Cent	Persistent Residual Urine Per Cent	Persistent Fistula Per Cent	Incontinence Per Cent
Suprapubic 2535 1st Stage	3.3	11.6	6.1	7.1	1.8	0.4	0.7
Suprapubic 3529 2nd Stage	4.4	4.8	2.9	2.9	1.0	1.0	0.9

RETROPUBIC PROSTATECTOMY

The retropubic approach to the prostate has been employed off and on in the last 30 years in many countries, but most operators discontinued its use because of the distressing complications.

Millin in London in 1947 revived the method when he reported his series of retropubic prostatectomies done in the preceding two years after painstaking dissection and study to perfect the method. Because of his writings and work American urologists have become active in using the retropubic approach.

The outstanding advantage of this operation is that, unlike the suprapubic approach, the bladder is not opened and traumatized or the prostatic adenoma blindly enucleated. Accurate visualization of the prostatic fossa and vesical outlet is obtained during the entire retropubic procedure.

The operation is performed through a skin incision just above the pubis. The prostate is exposed by dissecting through the space of Retzius between the undersurface of the pubis and the bladder, exposing the anterior surface of the prostatic capsule. Difficulties may be encountered in dissecting free the capsule because of a large plexus of veins overlying the prostate at this site. These must be divided to reach the capsule and may produce considerable hemorrhage. By making a transverse incision through the anatomic and surgical capsule (cortical prostate) a cleavage plane can be found and the adenoma enucleated. Because of this direct approach the entire prostatic bed is then under observation and bleeding vessels in the fossa can be ligated and fulgurated. The vesical neck is easily accessible and if contracted can be modified by removal of a wedge-shaped section from the posterior lip. Following the insertion of a urethral catheter the capsule is closed with catgut and the space of Retzius is drained. The catheter may be removed in four to 10 days.

In general, the operation has few of the complications of other methods and a shorter and smoother postoperative course than the suprapubic approach. It has certain advantages. At no time is there suprapubic drainage of urine, incontinence is rarely seen, and postoperative sexual function is good. There is excellent bladder drainage because the bladder is uninjured and the bleeding which does occur from the prostatic fossa rarely impairs catheter drainage from forming clots in the bladder.

There are contraindications to the retropubic approach. In the presence of

bladder pathology the transvesical approach must be used. An attempt to relieve urinary obstruction caused by a small adherent prostate and vesical neck contracture is difficult by this method. Abscess and suppurative prostatitis when present may be followed by osteitis pubis and infection of the space of Retzius. In the presence of large intravesical prostatic enlargement and subtrigonal and posterior lobe glandular hypertrophy, the retropubic approach meets with technical difficulties.

Millin, Souttar, and others have performed total prostatectomy by this route for cancer of the prostate and have removed the entire prostate with its capsule, the seminal vesicles, and the bladder neck. There is general agreement in America, however, that the total perineal or the combined perineal abdominal approach is most advantageous in the surgical treatment of cancer of the prostate.

At the present time in this country few have approached the large series of cases reported by Millin. The occurrence of osteitis pubis and the profuse hemorrhage which may follow exposing the prostatic capsule are the main disadvantages reported by American urologists Osteitis pubis may develop in 10 to 14 days or as late as five months after operation. Although recovery is spontaneous and is apparently unaffected by antibiotics, its occurrence greatly prolongs morbidity. Millin in his last reported series of 757 cases does not report osteitis pubis as a complication but cautions against periosteal trauma by needles or retractors. In 757 cases there were 33 deaths (4.4 per cent mortality) only 2 of which were due to pelvic cellulitis The incidence of suprapubic fistula was 4.5 per cent and of secondary hemorrhage 8 per cent Persistent incontinence occurred in only 2 cases.

In this country the original enthusiasm for the retropubic approach is waning. It is now recognized that the approach is technically difficult and that the complication of osteitis pubis is appreciable. This complication is so distressing to the patient that most surgeons have discarded the method. The incidence of osteitis pubis has been as high as 17 per cent in a series of 67 cases reported by Moore in which great care was taken to follow the technic of Millin Osteitis pubis rarely occurs with the suprapubic, transurethral, or perineal route. At the University of Chicago Clinics the retropubic approach has been abandoned. In a recent series of 300 consecutive prostatectomies the retropubic approach was used eleven times with 2 cases of osteitis pubis (18.2 per cent).

CARCINOMA OF THE PROSTATE

Carcinoma of the prostate is the most common cancer in the male. Necropsy studies have shown that 18 per cent of men over 50 have carcinoma of the prostate. R. A Moore and A. R. Rich stated that cancer of the prostate occurs in 8 to 14 per cent of men over 44 and other authors variously estimate the incidence as 14 to 29 per cent, based on random sections from prostatic specimens, to an incidence of 46 per cent when serial prostatic sections were used as a basis for study. Hinman estimates that at least 3,000,000 to 5,000,000, and possibly 8,000,000, Americans now have cancer of the prostate. The incidence of prostatic carcinoma follows a frequency distribution curve between the ages of 40 to 90 years, with the peak occurring between 60 and 70 years. In one series of 783 cases of cancer of the prostate the average age was 62 6 per cent. The natural course

of the untreated case has been described in a series of 485 patients with untreated cancer of the prostate. Thirty-one months was the average duration of life from the appearance of the first symptoms to death and 66 per cent of the patients with metastasis at the time of examination were dead within nine months. In a series of 273 patients untreated and without evidence of metastases only 10 per cent had survived five years.

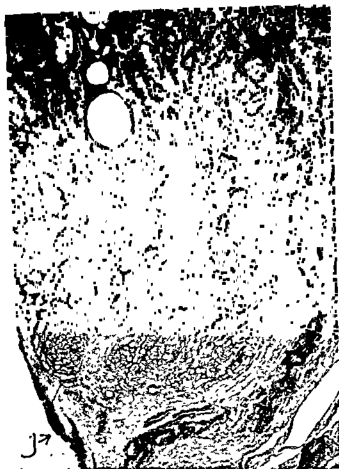


FIG 3 —Sagittal section of benign prostatic hypertrophy in man The arrow points to the *urethral mucosa. The tubules of the posterior segment (P) are on the right*

There is increasing evidence that the human prostate is a dual structure consisting of two functionally different areas and that in 75 per cent or more of the cases having cancer of the prostate the lesions begin in the posterior lobe (cortical region of the prostate) (Fig. 1). Histologic studies have shown that the neoplastic process begins in foci of aging and atrophic glandular tissue in the periphery of the prostate and may begin simultaneously in several areas of a given posterior lobe. The site of origin of the lesion in the periphery of the gland facilitates its *early diagnosis by rectal palpation when rectal examination is done.* However, the distance of its site of origin from the urethra results in delay of symptoms from urinary obstruction until the neoplastic process has developed to a point beyond the aid of surgery.

There is no known relationship between the occurrence of benign prostatic

hypertrophy and carcinoma of the prostate. Carcinoma of the prostate developing in the cortical region of the gland often occurs coincidentally with the benign prostatic hypertrophy of the medullary prostate and may involve by extension the hypertrophied areas of the gland (Fig. 2). Accordingly all surgical specimens following prostatectomy should be subjected to careful gross and histologic search for carcinoma.

The symmetrically enlarging adenoma of benign prostatic hypertrophy compresses the posterior lobe of the prostate into a thin cortical zone lying within the true prostatic fibrous capsule (Fig. 3). Transurethral resection often leaves much of this posterior lobe intact and suprapubic, retropubic, and perineal enucleation utilize a cleavage plane between this compressed posterior lobe or surgical capsule



Fig. 4.—Deformation of the urethra by carcinoma of the prostate arising in the posterior segment. Spheroidal aggregates of benign prostatic hypertrophy are present in the anterior segment.

and the true adenoma. Consequently, the tissue of the posterior lobe is left intact, attached to the true prostatic capsule. Since the tissue of the posterior or cortical prostate is the usual site of origin of carcinoma (Fig. 4), patients are in no wise offered any immunity from cancer of the prostate following prostatectomies by conservative technics and a histologically normal-appearing specimen removed at operation is no indication that carcinoma of the prostate is not also present.

Adequate surgical treatment of prostatic carcinoma necessitates early diagnosis of the lesion before it has spread beyond the capsule of the gland. In only 5 to 11 per cent of patients with cancer of the prostate is the lesion diagnosed early enough to effect a cure. Symptoms of urinary obstruction, of hematuria, and of pain from skeletal or regional metastasis occur only late in the disease. In most prostatic cancers the appearance of the lesion in the cortical prostate alters the

consistency of the gland to such an extent that rectal palpation is diagnostic or stimulates the examiner to further investigations to establish the presence or absence of cancer. Phosphatase determinations are useful in establishing the diagnosis. Significant elevations of acid phosphatase occur only in cancer of the prostate and then only when the lesion has metastasized or extended to periprostatic tissues, particularly lymph nodes. Although false positive determinations do not occur, the incidence of false negatives may be as high as 54 per cent. Because of these difficulties in preoperative diagnosis of the early lesion, positive diagnosis is often dependent on biopsy or histologic study of the surgical specimen.

Recent work using the G. N. Papanicolaou technic to examine urine or prostatic secretions for carcinoma cells has been reported to give accurate results even in early lesions. The method, however, requires considerable experience on the part of the examiner.

The only cure for cancer of the prostate is radical surgery in cases where the lesion has not extended beyond the prostatic capsule. To be eligible for radical surgery the patient must have no indication of the spread of the lesion beyond the prostate into the urethra or through the prostatic capsule, no roentgen ray evidence of bony metastases, no clinical evidence of metastases, and no elevation of the serum acid phosphatase.

The total or radical perineal prostatectomy of Young, in which the entire prostatic gland and capsule, seminal vesicles, and bladder neck (with part of the trigone) are removed, is the surgical technic employed for attempted cure of early lesions. Following exposure of the capsule, confirmation of the diagnosis is obtained by biopsy before the radical procedure is confirmed. The operation has undergone some modifications since Young's work and Belt has developed a modified route of perineal exposure which has distinct advantages.

The complications of total perineal prostatectomy are generally similar to those of subtotal perineal prostatectomy. However, the incidence of rectovesical fistula, urethral stricture, and persistent urinary incontinence is somewhat higher. Mortality from this operation has declined steadily from 9 per cent in Young's early series to a present incidence of about 3 per cent.

The results of the operation are generally good. Recent statistics indicate that 50 per cent of patients so treated are alive and apparently free from metastases of recurrence five years after operation. One series reports 28 per cent of 128 cases surviving 10 years following radical perineal prostatectomy and some of Young's patients lived 27 years

Patients demonstrating carcinomatous lesions of the prostate which do not satisfy the criteria for radical removal of the gland may be offered palliative endocrine treatment. Endocrine therapy is antiandrogenic and may be effected by either orchiectomy or the administration of estrogen. Orchiectomy is considered to offer somewhat better results than estrogen administration, but when the lesion fails to respond to the removal of androgen by orchiectomy estrogen may still yield palliation. Some 90 per cent of patients treated with antiandrogenic therapy show a distinct and immediate improvement. Within two years, 55 per cent of these are followed by relapse and within five years, 75 per cent are dead. About 20 per cent live more than eight to 10 years.

Following orchiectomy or estrogen therapy the immediate relief from pain and

cachexia may be followed by diminution in urinary obstruction in 20 to 30 days. Patients with marked prostatic obstruction from advanced carcinoma may require transurethral resection or cystotomy, but minimal or moderate obstruction may disappear as the neoplastic process diminishes under antiandrogenic therapy.

Orchiectomy is a simple procedure which may be done under local anesthesia and is easily tolerated by even debilitated patients. Side effects are hot flushes and impotence. The former is controlled by 1 mg. of diethylstilbesterol daily.

Treatment of carcinoma of the prostate by radiation has at best given palliative results in less than 30 per cent of the cases. Neither neoplastic tissue nor the interstitial cells of the testes show an effective response to radiation Deep roentgen therapy, however, is effective in controlling nerve root pains from vertebral and pelvic metastases in 50 per cent of cases and may give the patient some relief in the terminal stages of his illness.

TABLE I

THREE HUNDRED CONSECUTIVE PROSTATECTOMIES AT THE UNIVERSITY OF CHICAGO

Operation	*Suprapubic*		*Transurethral*		*Perineal*		*Radical Perineal*		*Retropubic*		*Over-all Total*	
Number of Operations	173		84		23		9		11		300	
	Cases	*Per Cent*	*Cases*	*Per Cent*	*Cases*	*Per Cent*	*Cases*	*Per Cent*	*Cases*	*Per Cent*	*Cases*	*Per Cent*
Mortality	2	1.16	1	1 19	2	8.7	0	0	0	0	5	1.66
Incontinence	4	2 3	2	2.38	3	13 0	2	23 2	0	0	11	3 68
Stricture	7	4 06	5	5 95	0	0	0	0	0	0	12	4 0
Fistula	3	1.74	0	0	0	0	1	11 1	0	0	4	1 33
Osteitis Pubis	1	0.58	0	0	0	0	0	0	2	18 2	3	1 0

REFERENCES

Abeshouse, B S. Comparison of Results in Treatment of Prostatic Obstruction by Transurethral Resection and Prostatectomy. *J Urol*, *42*·1101, 1939.

Abrams, M, Sedlezky, I, and Sterns, D B · Osteitis Pubis *New England J. Med*, *240*.637, 1949

Albers, D D, McDonald, J R, and Thompson, G. J.· Carcinoma Cells in Prostatic Secretions *J A M A*, *139* 299, 1949.

Alyea, E P. Early or Late Orchiectomy for Carcinoma of the Prostate *J Urol.*, *53*:143, 1945

Alyea, E P, and Henderson, A F: Carcinoma of the Prostate, Immediate Response to Bilateral Orchiectomy, Clinical and X-Ray Evidence *J A M.A*, *120*·1099, 1942.

Arnheim, F K Carcinoma of the Prostate A Study of Postmortem Findings in One Hundred and Seventy-six Cases *J. Urol*, *60* 599, 1948

Bacon, S K Retropubic Prostatectomy, Report of 102 Cases. *J. Urol*, *61*.75, 1949

Barnes, R W · *Endoscopic Prostatic Surgery* St Louis. C. V. Mosby Company, 1943.

Barnes, R W, Bergman, R T, and Farley, S. Histopathological Study of the Prostatic Tissue Following Endoscopic Prostatic Resection *J Urol.*, *57* 755, 1947.

Baron, E, and Angrist, A Incidence of Occult Adenocarcinoma of the Prostate after 50 Years of Age *Arch Path*, *32* 787, 1941

Barron, E S G, and Huggins, C. Citric Acid and Aconitase Content of the Prostate. *Proc Soc Exper Biol & Med*, *62*·195, 1946

Beatty, R P., Life Expectancy in Carcinoma of the Prostate; Five Year Survey of 88 Cases *J Urol*, *60*:264, 1948

Belt, E, Ebert, C E, and Surber, A C, Jr. New Anatomic Approach in Perineal Prostatectomy. *J Urol*, *41* 482, 1939

Biorn, C. L., and Greene, L. F.: Hemolysis during Transurethral Prostatic Resection. *Surg, Gynec. & Obst*, 88:389, 1949.

Bumpus, H. C, Jr Carcinoma of the Prostate; Clinical Study of 1000 Cases. *Surg, Gynec. & Obst*, 43:150, 1926.

Bumpus, H. C., Jr., Massey, B. D, and Nation, E. F.: Experience with Orchiectomy for Carcinoma of the Prostate. *J.A M A*, 127:67, 1945.

Chase, D. W., Burt, K. L., and Hess, E Orchiectomy in Treatment of the Carcinoma of Prostate. *Am. J. Surg*, 71:522, 1946.

Chute, R., and Williams, D. W.. Experiences with Stained Smears of Cells Exfoliated in Urine in Diagnosis of Cancer in the Genito-Urinary Tract; Preliminary Report. *J. Urol*, 59.604, 1948.

Colby, F. H.: Carcinoma of the Prostate, Total Perineal Prostatectomy. *S. Clin. North America, 27:1307, 1947.*

Colston, J. A. C.: Surgical Removal of Cancer of the Prostate Gland, Radical Operation. *J.A.M.A*, *127:69*, 1945.

Colston, J. A. C.. Carcinoma of the Prostate, Study of Percentage of Cases Suitable for Radical Operation. *J.A.M.A*, *122* 781, 1943.

Colston, J. A. C., and Brendler, H.: Endocrine Therapy in Carcinoma of the Prostate, Preparation of Patients for Radical Perineal Prostatectomy *J.A M A*, *134* 848, 1947.

Crane, J. J., and Rosenbloom, D Treatment of Carcinoma of the Prostate Gland, Comparative Study. *J. Urol.*, 53.411, 1945.

Creevy, C D: Importance of Hemolysis during Transurethral Prostatic Resection, Clinical Investigation. *J Urol*, 59.1217, 1948

Creevy, C D.: Hemolytic Reactions during Transurethral Prostatic Resection. *J Urol*, 58.125, 1947.

Creevy, C. D.: Diagnosis and Treatment of Early Carcinoma of the Prostate *J.A M.A*, 120 1102, 1942.

Culver, H, and Baker, W. J.: Carcinoma of the Prostate Gland. *Illinois M. J*, 92 282, 1947.

Davis, E.. Renaissance of Prostatectomy, with Particular Reference to Minimal Hospitalization without Preliminary Drainage. *J A M.A*, *119*:488, 1942; correction *119* 821, 1942.

Dean, A. L, Woodard, H. Q, and Twombly, G H.: Endocrine Treatment of Cancers of the Prostate Gland. *Surgery, 16.169, 1944.*

Deming, C L: The Correlation of Clinical Experience and Heterologous Growth of Human *Prostatic Cancer. J Urol, 61.281, 1949.*

Deming, C. L, and Neumann, C Early Phases of Prostatic Hyperplasia. *Surg, Gynec. & Obst., 68:155*, 1939.

Draper, J. W.: Twenty-seven Years of Prostatic Surgery at Bellevue Hospital, Study of Comparative Mortality Tests. *Surgery, 23* 515, 1948

Eikner, W C: One-Stage Suprapubic Prostatectomy with Primary Closure of the Bladder. *New York State J. Med*, 48.793, 1948.

Emmett, J L.: Transurethral Resection and Open Prostatectomy, Consideration Based on 10 Years of Experience with Transurethral Resection *Surg, Gynec. & Obst*, *79* 449, 1944

Emmett, J. L., and Greene, L F. Bilateral Orchiectomy for Carcinoma of the Prostate Gland, Clinical Experience. *J A M A*, *127*.63, 1945

Emmett, J L, and Hamm, R S: Bilateral Orchectomy for Carcinoma of the Prostate Gland, Preliminary Report. *S. Clin. North America*, 24.943, 1944

Flynn, J E.: Primary Carcinoma of the Prostate of 12 Years' Duration; Case Report. *J. Urol*, 55 626, 1946.

Gahagan, A. Q, and Fischman, J. L.: Carcinoma of the Prostate, A Statistical Study and Evaluation of Endocrine Therapy, with a Preliminary Report on an Additional Method of Treatment. *J. Urol*, *61* 587, 1949

Goldstein, A. E., and Rubin, S. W. Osteitis Pubis following Suprapubic Prostatectomy, Results with Deep Roentgen Therapy *Am. J. Surg*, *74*.480, 1947.

Grant, O, and Lich, R, Jr.. Rationale and Results in Retropubic Prostatectomy. *Ann. Surg*, 127.1010, 1948.

Grant, O., Lich, R., Jr., and Maurer, J.: Retropubic Prostatectomy. *Urol. & Cutan. Rev.*, 52:9, 1948.
Greene, L. F., and Emmett, J. L.: Further Observations on Treatment of Carcinoma of the Prostate by Bilateral Orchiectomy. S. *Clin. North America*, 26:1007, 1946.
Harrison, J. H.: Indications and Limitations of Prostatic Surgery in the Presence of Cardiac Disease. *Am. J. M. Sc.*, *204*:469, 1942.
Hatch, W. E.: Use of Oxycel in Prostatic Resections. *J. Urol.*, *59*:887, 1948.
Herbut, P. A.: Cytologic Diagnosis of Carcinoma of the Prostate. *Am. J. Clin. Path.*, *19*:315, 1949.
Herbut, P. A., and Lubin, E. N.: Cancer Cells in Prostatic Secretions. *J. Urol.*, *57*:542, 1947.
Higbee, D. R.: Status of Perineal Prostatectomy Today. *J.A.M.A.*, 139:141, 1949.
Hinman, F.: The Early Diagnosis and Radical Treatment of Prostatic Carcinoma. *California Med.*, *68*:338, 1948.
Hinman, F.: The Obstructive Prostate. J.A.M.A., *135*:136, 1947.
Hinman, F., Jr., and Hinman, F.: Occult Prostatic Carcinoma Diagnosed upon Transurethral Resection. *J. Urol.*, 12:723, 1949.
Huggins, C.: Endocrine Substances in the Treatment of Cancers. J.A.M.A., *141*:750, 1949.
Huggins, C.: Androgen and Anaplasia (Edgar Allen Memorial Lecture). *Yale J. Biol. & Med.*, 19:319, 1947.
Huggins, C.: Etiology of Benign Prostatic Hypertrophy. *Bull. New York Acad. Med.*, 23:696, 1947.
Huggins, C.: Prostatic Cancer Treated by Orchiectomy, Five Year Results. J.A.M.A., *131*:576, 1946.
Huggins, C.: Physiology of the Prostate Gland. *Physiol. Rev.*, 25:281, 1945.
Huggins, C.: Effect of Orchiectomy and Irradiation on Cancer of the Prostate. *Ann. Surg.*, *115*:1192, 1942.
Huggins, C., and Hodges, C. V.: Studies on Prostatic Cancer; Effect of Castration, of Estrogen, and of Androgen Injection on Serum Phosphatases in Metastatic Carcinoma of the Prostate. *Cancer Research*, *1*:293, 1941.
Huggins, C., and Johnson, M. A.: Cancer of the Bladder and Prostate. J.A.M.A., *135*:1146, 1947.
Huggins, C., and Stevens, R. A.: Effect of Castration on Benign Hypertrophy of the Prostate in Man. *J. Urol.*, *43*:705, 1940.
Huggins, C., and Webster, W. O.: Duality of the Human Prostate in Response to Estrogen. *J. Urol.*, *59*:258, 1948.
Huggins, C., Scott, W. W., and Hodges, C. V.: Studies on Prostatic Cancer; Effects of Fever, of Desoxycorticosterone, and of Estrogen on Clinical Patients with Metastatic Carcinoma of the Prostate. *J. Urol.*, *46*:997, 1941.
Huggins, C., Stevens, R. E., Jr., and Hodges, C. V.: Studies on Prostatic Cancer; Effects of Castration on Advanced Carcinoma of the Prostate Gland. *Arch. Surg.*, 43:209, 1941.
Jacobs, A.: Recent Trends in the Treatment of Prostatic Obstruction. *Brit. M. J.*, *1*:1231, 1948.
Jewett, H. J.: Radical Perineal Prostatectomy for Cancer of the Prostate, an Analysis of 190 Cases. *J. Urol.*, *61*:277, 1949.
Jewett, H. J.: Urogenital Malignancies. *Chicago M. Soc. Bull.*, 50:443, 1947.
Kahler, J. E.: Carcinoma of the Prostate Gland, Pathologic Study. J. *Urol.*, *41*:557, 1939.
Lavalle, L. L., and Hamm, F. C.: Osteitis Pubis; Its Diagnosis and Treatment. *J. Urol.*, *61*:83, 1949.
Lazarus, J. A.: Questionable Cancer of the Prostate Gland; Clinical versus Routine Pathologic Evidence. *J. Urol.*, 55:618, 1946.
LeDuc, I. E.: Anatomy of the Prostate and Pathology of Early Benign Hypertrophy. *J. Urol.*, 61:930, 1949.
Lewis, L. G.: Carcinoma of the Prostate: Young's Radical Perineal Prostatectomy. *J. Urol.*, 47:302, 1942.
Lich, R., Jr., Grant, O., and Maurer, J. E.: Extravesical Prostatectomy, A Comparison of Retropubic and Perineal Prostatectomy. *J. Urol.*, *61*:930, 1949.

Lowsley, O. S.: The Development of the Human Prostate Gland, with Reference to Development of Other Structures at the Neck of Urinary Bladder. *Am. J. Anat.*, 60.274, 1912.

Lowsley, O. S., and Gentile, A.: *Retropubic Prostatectomy. J. Urol*, 59:281, 1948.

Millin, T. Retropubic Prostatectomy J. Urol., 59:267, 1948.

Millin, T *Retropubic Urinary Surgery*. Edinburgh: E. & S. Livingstone, 1947.

Millin, T., Macalister, C. L. O., and Kelly, P. M: Retropubic Prostatectomy; Experiences Based on 757 Cases. *Lancet*, 256.381, 1949.

Moore, R A.: Benign Hypertrophy of the Prostate; Morphological Study. *J. Urol*, 50.680, 1943.

Moore, R A.: Morphology of Small Prostatic Carcinoma. *J. Urol.*, 33.224, 1935.

Moore, T. D.: Experiences with Retropubic Prostatectomy. *J. Urol.*, 61.46, 1949.

Munger, A. D.: Treatment of Carcinoma of Prostate by Irradiation. *Radiology*, 45:31, 1945.

Munger, A. D: Experiences in Treatment of Carcinoma of the Prostate with Irradiation of the Testicles *J. Urol*, 46.1007, 1941.

Myers, G M: Occurrence of Carcinoma in Clinically Benign Prostatic Obstructions. *Colorado Med*, *34.248, 1937.*

Nelson, O A: Modified Technique in Suprapubic Prostatectomy. *Urol. & Cutan. Rev*, 53 1, 1949.

Nesbit, R. M.: Transurethral Prostatectomy Springfield, Ill.: C. C. Thomas, 1943.

Nesbit, R. M., and Cummings, R. H.: Prostatic Carcinoma Treated by Orchiectomy, Secondary Report Based on 75 Cases Observed for at Least 21 *Months Following* Operation. *J A M A*, *124* 80, 1944

Nesbit, R. M., and Plumb, R. T.: Prostatic Carcinoma, Follow-up on 795 Patients Treated *Prior to the Endocrine Era and Comparison of Survival Rates between These and Patients* Treated by Endocrine Therapy. *Surgery*, 20.263, 1946

Nesbit, R M., and Plumb, R. T.. Prostatic Carcinoma Treated by Orchectomy; Third Report Based on 75 Cases Observed for at Least 35 Months Following Orchectomy. *Univ. Hosp. Bull*, *Ann Arbor*, 12:2, 1946.

Nesbit, R. M., and Ryan, J A. Prostatic Surgery in University of Michigan Hospital in 1946. Urol. & Cutan Rev., 51.452, 1947

Nesbit, R. M, Pazzos, R, and Cummings, R. H.: Treatment of Prostatic Carcinoma by Castration and by Administration of Estrogenic Hormone; Comparison of Clinical Response. *J. Urol*, 52 570, 1944

Ormond, J. K Radical Perineal Prostatectomy for Carcinoma *J. Urol*, *58.61, 1947.*

Ormond, J. K.. Radical Perineal Prostatectomy for Carcinoma of the Prostate. *Surgery*, 20:257, 1946.

Palomo, A: Carcinoma of the Prostate Gland. *J Urol*, *53*.166, 1945.

Papanicolaou, G N: Diagnostic Value of Exfoliated Cells from Cancerous Tissues. *J.A M A.*, *131:372, 1946.*

Pressman, D., and Rolnick, H. C. Retropubic Prostatectomy. *J. Urol*, *61*:59, 1949.

Quinby, W. C.: Hemostasis by Thrombin and Fibrin Foam in Suprapubic Prostatectomy; Analysis of 40 Cases *New England J. Med*, *235.609*, 1946.

Rich, A. R.: On the Frequency of Occurrence of Occult Carcinoma of the Prostate. *J. Urol*, *33* 215, 1935.

Rodriguez Molina, L. F· Prostatectomy versus Transurethral Resection. *Urol. & Cutan. Rev*, *51*:459, 1947.

Rose, D K.· Simplified Suprapubic *Prostatectomy. J. Urol*, *53*.470, 1945.

Rose, D. K: Combined Surgical and Hormonal Treatment for Cancer of the Prostate. *S. Clin. North America*, *24*:1203, 1944.

Rosenberg, M. L., and Vest, S. A: Osteitis Pubis. *J. Urol.*, 60 767, 1948.

Scott, W. W, and Benjamin, J. A: A Comparative Follow-up Study of the Therapeutic Value of Bilateral Orchiectomy in *Treatment of* Carcinoma of the Prostate Gland. *J. Urol*, 60.604, 1948.

Seaman, J. A., Connelly, A J., and Egnatz, N.: Follow-through on 100 Cases of Cancer of the Prostate. *J. Urol.*, 57.1158, 1947.

Shivers, C H deT, and Groom, C E. Prolonged Morbidity following Operation for Benign Prostatic Hyperplasia, Statistical Survey *J Urol*, 59.893, 1948.

Stock, F E, and Wells, C Suprapubic Prostatectomy, History, Development and Modern Technique *Urol & Cutan Rev*, 52 313, 1948

Stump, G D, and Thumann, R C, Jr. Preliminary Report of a Method of Primary Closure of Suprapubic Prostatectomy Using Oxidized Cellulose. *J. Urol*, 59.202, 1948

Taylor, J A, and Place, C H Evaluation of Transurethral Prostatectomy. *J.A M A*, 139.144, 1949

Twinem, F P, and Davalos, A Radical Surgery in Prostatic Carcinoma. *J. Urol*, 61.575, 1949

Vest, S A, and Frazier, T H Survival following Castration for Prostatic Cancer. *J Urol.*, 56 97, 1946

Wear, J B, and Schoenenberger, A P Carcinoma of the Prostate, 12 Year Review. *J Urol*, 59 587, 1948

Wilhelm, S F, and Freed, S Z Postoperative Stricture and Periostitis Pubis following Retropubic Prostatectomy *J Urol*, 62 660, 1949

Woodard, H Q, and Dean, A L The Significances of Phosphatase Findings in Carcinoma of the Prostate *J Urol*, 57 158, 1947

Young, H H Cure of Cancer of the Prostate by Radical Perineal Prostatectomy (Prostato-Seminal Vesiculectomy), History, Literature and Statistics of Young's Operation. *J. Urol*, 53 188, 1945

Some Congenital and Developmental Problems of the Hip Joint in Infancy and Childhood

FRANK P. KREUZ, CAPT., M.C., U.S.N., AND ALFRED R. SHANDS, JR., M.D.

The subject of the congenital and developmental hip lesions still enjoys a priority in interest among orthopedic surgeons. This interest stems not only from the extremely controversial nature of the subject, but also from the fact that these lesions as a group constitute a large percentage of the crippling affections of infancy and childhood. The fundamental problem in all these conditions is the same; a clarification of our concepts of the growth and development of the hip. Although the most striking changes in development take place during embryonal and fetal life, the ultimate form and dimensions of the hip are not attained until the period of growth ceases Significant changes occur, especially in early infancy and childhood, designed to prepare the structures for erect ambulation. Birth, therefore, is only an incident in the growth and developmental process.

PRENATAL DEVELOPMENT OF THE HIP

It is customary for textbooks to discuss the embryology of the hip from the standpoint of the skeletal structures alone, without a correlation of the embryology of the soft parts. Such a concept is misleading. It is known that the neuromuscular system is sufficiently developed in the embryo of about eight weeks to permit spontaneous movement (Coghill, Arey) and that muscle differentiation begins [illegible]

edged by Werndorf, and Strayer even suggested that muscle innervation and function might have an influence over the time of opening of the hip joint. These observations lead one to believe that there is a continuous complimentary relationship between the developing skeleton and muscles in the embryology of the hip

The hip joint develops from the lower limb bud which contains the anlage for the innominate bone as well as the lower extremity. It originates as a protuberance on the anterolateral aspect of the abdominal wall at about the level of the fifth lumbar vertebra in the 3 to 4 mm. (four weeks) embryo (Strayer) (Fig. 1). Both the innominate bone and lower extremity undergo a characteristic change in position as growth proceeds The innominate bone is at first perpendicular to the vertebral column, but later (20 mm. embryo) rotates downward and parallel to the vertebral column opposite the third to the fifth sacral vertebrae. This rotation

is accompanied by a definite change in the shape of the innominate bone, especially the ilium (Fig. 2). The lower extremity undergoes several changes in position. At first it points downward parallel with the vertebral column, and seems

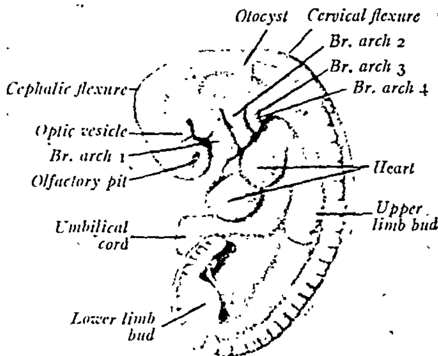


FIG 1 —Human embryo of 5 mm. viewed from the left side (after His). ×10

disproportionately large; next, it bends forward with the knees and feet turned outward, and finally, the limb undergoes an internal rotation of 90°. This synchronous rotation of the pelvis and lower limb, each on its own axis, is accompanied by a concomitant development and change in position and leverage of the



FIG 2.—The cartilaginous skeleton of the human lower extremity (adapted after Bardeen) Left, at 14 mm. when chondrification is well begun (×20); right at 20 mm. when chondrification is well advanced (×15).

various muscles attached to the pelvis and femur The exact cause and mechanism of limb rotation are not known, but it would seem that there are two factors involved, e.g., an intrinsic factor of bone growth, and an extrinsic factor of muscle tension or traction (Carey). An orderly and synergistic rotation of both parts of

the limb bud with its surrounding musculature is therefore necessary for the development of the joint.

It is generally agreed that the hip joint is completely formed by the 10th week (Stewart, McDermott, and Howorth). However, De Santo and Colonna observed that the *capsule* did not become differentiated until the 20th week. Various shapes have been ascribed to the head of the femur during intra-uterine life. Some have found it to be perfectly round in all stages of development (Strayer and Howorth), while others have found the head to be rectangular (Stewart) or club-shaped (De Santo and Colonna). The latter suggest that a certain amount of remodeling of the head may take place in intra-uterine life, and thus an abnormally shaped head may become perfectly round by birth.

Before the joint opens, the acetabulum is usually thought to be very shallow, gradually deepening until the 14th week when it resembles that of the newborn. According to Le Damany, however, the socket is hemispheric in the first six months of intra-uterine life and then the depth gradually diminishes until birth, when the cavity is reduced to one-third of a sphere. De Santo and Colonna also found the socket extremely shallow in fetuses up to 30 weeks. Ossification of the acetabulum begins in the iliac portion in about the 20 mm. embryo, and its relative proportion to that of the other bones forming the socket is the same as at birth, e.g., 2/5 ilium, 2/5 ischium, and 1/5 pubis. Nothing is known of the relationship of the developing acetabulum to the vertebra in the lateral plane during embryonal and fetal life, but we can assume that certain changes do take place as a result of the reciprocal rotation of both portions of the limb bud. Le Damany regards the increased development of the posterior portion of the acetabulum (ischial portion) as characteristic of human acetabular development. This could also be explained on the basis of the downward and medial rotation of the innominate bone.

Howorth studied the motion of the hip joint in three to six month fetuses and found relatively normal motion except for extension which was limited to about 145°, owing to what he terms "a twist in the capsule." With the hip in flexion, the fibers of the capsule run parallel to the neck, and on extension they tighten by torsion. He considered this limitation of extension by the twisting of the capsule to be a specific phase in the development of the hip joint. These findings are what one might expect from a relatively contracted iliofemoral ligament resulting from the extremely flexed position of the fetus *in utero* and a changed relationship of the capsular structures due to the rotation of the lower limb on the axis of the hip joint.

An analysis of the changes that occur in the neck of the femur is of considerable importance. As a result of the rotation of the two portions of the limb bud, certain changes take place in the neck of the femur. The neck rotates on its own axis as well as on the axis of the femur. As the neck rotates on the axis of the femur, it causes a bending in relation to the longitudinal axis of the femur (the neck-shaft angle). As the neck bends on its own axis, a torsion of the neck in relation to the condyles of the femur results (the angle of anteversion of the neck). If the condyles of the femur are placed on a flat surface, the neck of the femur will usually point forward, producing an angle with the horizontal which is called the angle of anteversion of the neck. If the neck is directed backward, there is an "angle of

is accompanied by a definite change in the shape of the innominate bone, especially the ilium (Fig 2). The lower extremity undergoes several changes in position. At first it points downward parallel with the vertebral column, and seems

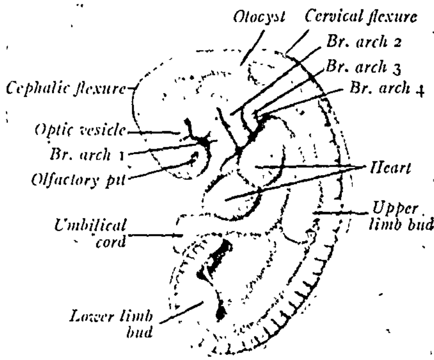


Fig. 1 –Human embryo of 5 mm. viewed from the left side (after His). ×10.

disproportionately large; next, it bends forward with the knees and feet turned outward, and finally, the limb undergoes an internal rotation of 90°. This synchronous rotation of the pelvis and lower limb, each on its own axis, is accompanied by a concomitant development and change in position and leverage of the

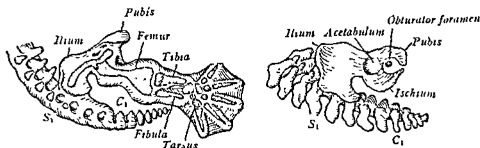


Fig. 2 –The cartilaginous skeleton of the human lower extremity (adapted after Bardeen). Left, at 14 mm. when chondrification is well begun (×20), right at 20 mm. when chondrification is well advanced (×15).

various muscles attached to the pelvis and femur. The exact cause and mechanism of limb rotation are not known, but it would seem that there are two factors involved, e g , an intrinsic factor of bone growth, and an extrinsic factor of muscle tension or traction (Carey). An orderly and synergistic rotation of both parts of

ovea centralis, and the cavity of the acetabulum were rich in blood vessels, but hat "the vessels do not appear to penetrate the head." Kolodny and Jones and Lovett also share in this opinion, the latter writing: "The vessels of the ligamentum teres present in early life supply only a small portion of the articular surface and are of no importance."

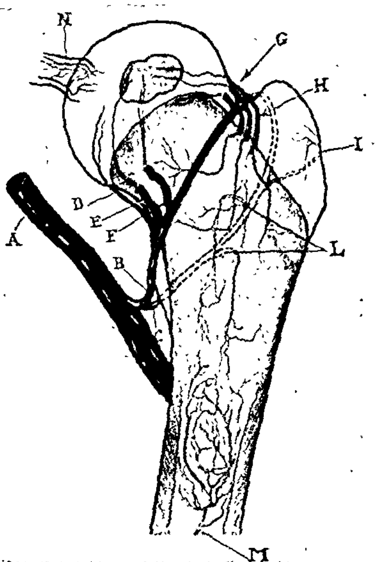


FIG 3 – Schematic drawing of the blood supply of the head and neck of the femur from an injected specimen at the age of two years. (A) *Profunda* femoral artery, (B) medial (posterior) femoral circumflex artery, (C) lateral (anterior) *femoral* circumflex artery, (D, E, and F) inferior retinacular branches of the medial (posterior) femoral circumflex artery, (G and H) superior retinacular branches of the *medial* (posterior) femoral circumflex artery, (I and L) trochanter and neck branches from the *lateral* (*anterior*) circumflex artery, (M) nutrient artery; (N) ligamentum *teres* vessels.
(After Logroscino)

In an article entitled, "A Note on the Retinaculum of Weitbrecht," the British anatomist, *Wamsley*, *has* given an excellent description of the blood supply of the central nucleus of the head and the metaphysis of the neck of the femur. He

retroversion." The development of the condyles of the femur, therefore, is a factor in the development of the normal angle of anteversion of the neck of the femur. Unless viewed in three dimensions, the bending and torsion of the neck of the femur appear confusing. When one views a femur from the front, the neck-shaft angle may appear to be greatly increased (coxa valga), whereas when the femur is simply internally rotated, the angle is found to be normal This is due to the anteversion of the neck

It is generally agreed that the angle of anteversion of the neck of the femur is zero at about the time of differentiation of the hip joint (eight weeks) and that it gradually increases to about 35° at birth (Le Damany et al.). There is no such agreement on the formation of the neck-shaft angle, however, opinions vary from an estimate of 90° at the time of differentiation of the hip joint increasing to as much as 160° at birth, and findings of 140° in the 20 mm embryo and decreasing to 110 to 120° at birth (Howorth). Since anteversion of the neck of the femur increases in intra-uterine life even after the rotation of the limb bud has been completed, it can be assumed that extrinsic factors such as muscle action and/or the forced ovoid position of the fetus *in utero* are factors in the development of the changes in the neck of the femur.

Nothing has been written on the part, if any, played by the developing vascular system in influencing the embryologic development of the hip. There have been many contributors to our knowledge of the developing blood supply of the hip joint, however, including Schwartz, Kolodny, Logroscino, Nordinson, Wolcott, Sherman, Chandler, Kreuscher, Lippmann, Zemansky, Strayer, De Santo and Colonna, and others, including an interesting unpublished study by Green and Cohn at the Children's Hospital in Boston All are in agreement that the acetabular region and the ligamentum teres are supplied by the obturator artery and that evidence of rich vascularization of this area is already present shortly after the differentiation of the hip joint. At about this time, too (37 mm. embryo) the first invasion of blood vessels to the femur takes place at the site of the adult nutrient artery (Strayer) As we are especially concerned with the blood supply of the central portion or epiphysis of the head and the metaphysis of the neck, we carefully reviewed the voluminous literature in this light.

We were particularly interested to know whether or not the vessels of the ligamentum teres contributed to the blood supply of the central nucleus of the head in prenatal and early postnatal life, and we found no convincing evidence. In almost every instance in which the vessels of the ligamentum teres were credited with aiding in the blood supply of the head, critical analysis disclosed that the authors either did not specify the portion of the head supplied by the vessels of the ligament, or that the vessels did in fact supply only a small portion of the periphery or articular surface and never did reach the central nucleus. Through the courtesy of Dr. Green and Dr Cohn, one of the writers was permitted to examine their fetal specimens of all ages in which the aortas were injected with a barium-latex solution at a pressure of 220 to 250 mm mercury. In no case did the vessels of the ligamentum teres extend any farther than a short distance from the articular surface and in almost all of them the vessels actually stopped abruptly at the fovea centralis. These observations corroborate the findings of De Santo and Colonna, who observed that in the 20 week embryo the ligamentum teres,

The superior and inferior gluteal vessels which ramify in the posterior aspect of the hip are mainly concerned with the blood supply of the capsule, and do not directly contribute to the supply of the central nucleus and metaphysis.

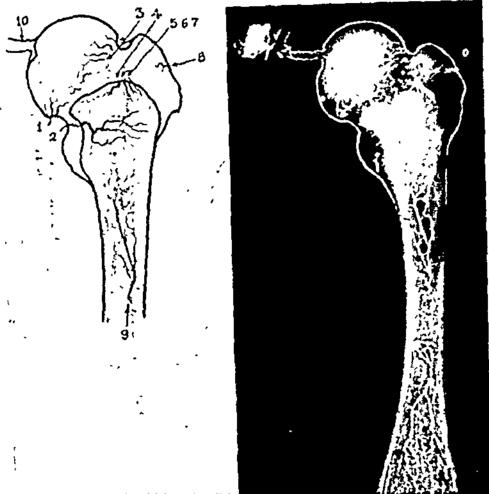


Fig. 5 –Drawing and arteriogram of the blood supply of the head and neck of the femur at the age of nine months. (1) and (3), superior and inferior retinacular branches from the medial (posterior) femoral circumflex artery to the central nucleus of the head; (4, 5, 6, and 7) branches from the lateral (anterior) femoral circumflex to the metaphysis and the neck; (2) artery to the inferior portion of the neck from the lateral (anterior) femoral circumflex; (8) small trochanteric branch from the lateral (anterior) femoral circumflex, (9) diaphyseal vessel from the nutrient artery; (10) ligamentum teres vessels.
(After Logroscino)

The most recent contribution was made by Tucker who studied the blood supply of 44 femurs obtained from fresh cadavers, the ages varying from birth to 77 years. He made the following deductions:

(1) The cartilaginous head and ossification center in children are supplied almost entirely from retinacular arteries, consisting of three main groups, (a) posterosuperior, (b) posteroinferior, and (c) anterior. The posterosuperior arteries are the largest. The anterior group is the smallest and least constant, its vessels being derived from the lateral femoral circumflex, whereas the posterior

pointed out that the blood vessels which perforate the capsular attachment and pass along the periphery of the neck enter the foramina toward the articular margin of the head and terminate in the epiphysis of the head and the metaphysis of the neck. From the points where they perforate the capsule, these vessels derive and carry inward indefinite fibrous prolongations of the capsule wall which are covered over or completely invested by reflections of synovial membrane. These elements constitute the retinaculum of Weitbrecht. Strayer found that in the 70 mm embryo (about three months), blood vessels enter the head and neck of the femur and that this vascular ring about the neck enclosed by the retinaculum of Weitbrecht comes from the medial (posterior) and lateral (anterior) circumflex femoral branches of the profunda femoral artery. A study of injected specimens would seem to indicate that the medial circumflex femoral is mainly concerned with the blood supply of the central nucleus, and that the lateral circumflex is mainly concerned with the blood supply of the metaphysis (Logroscino, Wolcott, Green and Cohn) (Figs. 3, 4, and 5). It is particularly interesting



FIG 4.—Drawing and arteriogram of the blood supply of the head and neck of the femur at the age of two years, showing the arteries as indicated in the schematic drawing in Fig. 3. (After Logroscino)

to note that both the arteries to the nucleus and those to the metaphysis are probably end arteries during the growth of the femur (Warmsley; Logroscino) and do not anastomose until the disappearance of the epiphyseal plate (Fig. 6). These observations tend to support Green's admonitions regarding the handling of the posterior capsule in operations for slipped femoral epiphysis, because of the danger of interfering with the blood supply of the nucleus when the medial femoral circumflex, which ramifies in the posterior capsule, is damaged Although these vessels are rather loosely embedded in the superficial layer of the periosteum (Kolodny) and can be stretched and displaced to certain limits without tearing, their importance to the future development of the hip should always be kept in mind.

activity of the gluteus maximus. The external rotation of the thigh decreases as a result of the action of the internal rotators and the gluteus medius, which is a strong internal rotator of the thigh with the hip in flexion. The socket deepens as the head is held snugly within its cavity by pressure mainly from the action of the three muscles which extend from the spinal column to the femur—the iliopsoas, the gluteus maximus, and the pyriformis. The posterior rim of the socket is accentuated by the action of crawling. There is a tendency for the head to project anteriorly because of the anteversion of the neck, but it is probably checked by the strength and twisting of the anterior capsule as the thigh is extended. This mechanism, aided by the constant inward and outward rotation of the head in the socket during the act of crawling, could explain the gradual decrease in anteversion of the neck during this stage of development. As erect posture is assumed, there is a relative increase in the development and strength of the muscles of the lumbar spine. The exaggerated curve of the lumbar spine is due to the flexion contracture of the hips and to an attempt to attain balance with insufficient erector spinae muscle strength. The forces of rotation within the hip joint are now mainly directed at the superior rim of the acetabulum.

The knee joint also takes part in the reciprocal postnatal development of the hip. As the child kicks in the recumbent position there is a gradual increase in extension of the knee joint. When the last few degrees of complete extension are developed, there is a slight external rotation of the tibia on the femur owing to the development of the internal condyle. In the erect posture, however, the tibia is fixed, and therefore the last few degrees of complete extension of the knee produce an internal rotation of the femur on the tibia. This internal rotation of the femur on the tibia in walking is especially prominent when the knee is fully extended and the hip is slightly flexed because of the internal rotation action of the gluteus medius. It cannot take place as long as the knee remains in slight flexion. The medial hamstrings, especially the gracilis, as well as the iliotibial band, also exert an influence on the development of the hip in the walking stage. With the hip in flexion and the knee extended, the gracilis will tend to displace the greater trochanter laterally when the thigh is adducted, but this action is neutralized by the powerful force of the iliotibial band. One of the most important factors in the struggle for stability during the early phases of walking is the constantly attempted inward rotation of the outwardly rotated extremity (Krida) and this serves as the best guarantee of a well formed hip. The process of remodeling of the hip during the recumbent, crawling, and walking stages of development is a complicated mechanism involving both the knee and the hip as well as the spine and the muscles which activate them. As growth proceeds and the mechanism of these forces is altered and increased by the demands of environment with its many traumatic incidents, the incidence of puberty, and other factors, the problems become even more involved and more difficult of solution.

CONGENITAL DISLOCATION OF THE HIP

The term congenital dislocation of the hip is not completely accurate because it implies that the condition was present at birth. The available evidence in the extensive literature on the subject negates this implication Few cases of actual

group comes from the medial femoral circumflex. The retinacular vessels lie loosely under the synovial membrane, sometimes in mesenteric-like folds of synovial membrane

(2) The arteries of the ligamentum teres were small in children and penetrated the deep cartilage or ossification center in only 8 out of 24 cases. (He did not, however, specify the exact ages in which these 8 "penetrations" occurred.)

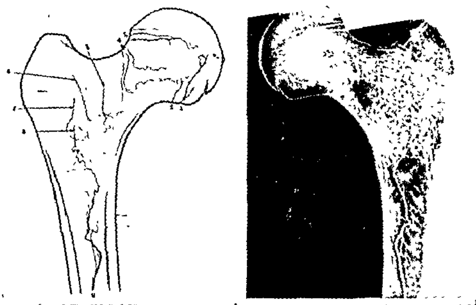


Fig 6 —Drawing and arteriograph of the blood supply of the head and neck of the femur after the disappearance of the epiphyseal plate, showing anastomosis between the vessels of the head and metaphysis
(After Logroscino)

(3) The ligamentum teres vessels never constitute the chief vascular supply to the head in children

(4) In adults, the retinacular vessels are still prominent but the arteries of the ligamentum teres take over an increasing share in the blood supply of the head. The ligamentum teres arteries increase in size with age

(5) The retinacular vessels are the chief supply to the epiphysis and femoral head at all ages

POSTNATAL DEVELOPMENT OF THE HIP

At birth the hips are flexed and the thighs externally rotated, the legs are relatively short and the spinal column presents one long flexion curve. There is a flexion contracture of the hips of about 35° There is anteversion of the neck of the femur of about 35° The hip sockets are shallow. As the infant unbends and development proceeds through the sitting and crawling stages, these abnormalities gradually decrease. The flexion contracture of the hip diminishes owing to the stretching of the contracted muscles, fascia, and capsular structures, and the

Konde and Allam found congenital hip dysplasia in shepherd dogs, the former considering it hereditary in nature.

Greene, Hu, and Brown of the Rockefeller Institute crossed wild stocks of rabbits under domestic conditions and found hip dysplasias comparable in many ways to those seen in man and dogs.

In a study of "congenital malformations induced in rats by maternal nutritional deficiency," Warkany showed that a great many factors can interfere with the normal development of the embryo. He found that a riboflavin-deficient diet in the mother affected the growth of the embryo at about the stage of chondrification of the skeletal blastema (second week) and produced various forms of skeletal malformations including "suggestive acetabular deformities." Exposure to actinic rays before or at the stage of chondrification produced the same types of deformities. A diet deficient in vitamin D produced deformities of a different pattern, e.g., bowing of the long bones and deformities of the rib cage. Warkany concluded that the defects in ossification are secondary and result from the faulty development of the precursors of bone.

Moore sectioned the peripheral nerves of 78 cases of various congenital deformities and found pathologic changes in almost 100 per cent. Twenty-four cases showed the typical lesions of neurofibromas. Although he did not consider the nerve lesions the cause of the deformity, he suggested that *the nervous system may have an unrecognized function in co-ordinating and guiding the growth processes.* Barber is given credit for being the first in the American medical literature to show the close relationship between congenital bowing of the tibia and congenital pseudarthrosis to von Recklinghausen's disease (neurofibromatosis).

Hart, citing Faber's work, concluded that the hereditary factor is the primary factor in hip and acetabular dysplasia, and that the dysplasia or flat socket with or without dislocation is the clinical expression of the same gene-conditioned chromosome. He considers the actual dislocation to be a secondary phenomenon which may develop either during intra-uterine life or during the first or second year of postnatal life.

Badgley, in an excellent paper on the "Correlation of Clinical and Anatomical Facts Leading to a Conception of the Etiology of Congenital Hip Dysplasia," presents a refutation of the hereditary "acetabular dysplasia" theory of Faber and Hart. He referred to Scaglietti's report of 478 cases of preluxation of the hip in the first year of life, all demonstrating Putti's diagnostic triad, in which 94 per cent had excellent results following Putti's simple method of treatment in abduction and internal rotation. Badgley states that if there had been a primary inherent defect in the acetabulum, 94 per cent of these hips could not have developed normally. According to Badgley, the primary dysplasia of the hip is produced by an increased anteversion of the neck with a concomitant loss of the reciprocal position of the head in the acetabulum. This he believes is due to "an embryonic arrest of rotation of the fetal limb," which, he states, does not occur in animals. Carey, in his voluminous study of the development of the femur in pigs, on the other hand, has shown conclusively that the lower extremity rotates through an arc of 90°, as in humans. This disparity in views may be due to the fact that little significance has been attached to the rotation of the innominate

dislocation could be found to have occurred in prenatal life or to have been discovered shortly after delivery. Although intra-uterine dislocation probably does occur, as Chandler's case shows, there are too many complicating and unusual features from which to draw conclusions.

Many surgeons, including Hart and Badgley, have suggested the term "congenital hip dysplasia with or without dislocation" and this seems more appropriate. But if we regard the development (embryology) of the hip from the broad viewpoint of a continuity of growth from prenatal and postnatal life, until its function of weight-bearing and ambulation in the erect posture is attained, birth becomes a mere incident in the "plasia" of the human hip. Le Damany speaks of the normal malformation of the hip at birth, and points to the flat socket and anteversion Most authors agree with him that a certain amount of flattening of the socket and a high degree of anteversion are normal at birth, yet these are the very conditions which predispose the infant to hip dysplasia. It is true that hips which were considered dysplastic at birth have developed into normal hips and isolated spontaneous cures of congenital subluxation of the hip have been recognized and reported (Drehmann). But it is also true that hips which were considered to be normal at birth have subsequently developed a dysplasia. The process of remodeling of the hip in infancy and childhood is therefore probably a most important factor in the eventual formation of the hip. It suggests the possibility of our assisting in this remodeling process and thereby decreasing the incidence of hip dysplasias. It may be correct to consider all hips potentially dysplastic at birth, and actual dysplasia in some cases at least may be the result of postnatal growth and development and therefore strictly speaking not truly congenital.

Etiology of Congenital Hip Dysplasia

The etiology of hip dysplasias is unknown, but there are certain popular theories which should be discussed in the light of the prenatal and postnatal development of the hip.

Until recently it has been commonly considered that hip dysplasias were the exclusive inheritance of man (Jansen). Genetic investigations, therefore, had to do mainly with an investigation of the families of children with congenital dislocation of the hip Faber found flat sockets in many of these families and considered these individuals genetically abnormal and latent carriers of the "hip dysplasia gene" Murk Jansen also considered the flattened hip socket as the cause of hip dysplasias, not on the basis of heredity, but on the basis of causing an alteration of the stresses on the femoral head and neck, the deformation of the socket depending on the degree of softening of the skeletal structures and the intensity of the forces acting upon them

Stockard found shallow sockets in bulldogs which predisposed them to dislocation of the hips, the dislocation being first noticed when the dog began to stand and walk. The skeletons of adult bulldogs sometimes showed old congenital dislocations that were not apparent in the living animal. He also found that hybrids between the bulldog and shepherd did not have shallow acetabuli He concluded that bulldogs have genetic factors for dystrophy of the shoulder and pelvic girdle.

(Morrison), inherent relaxation of the tendons and ligaments about the hip developing after birth (Vogt), failure of ossification of the head and acetabulum due to insufficient pressure of the head in the socket (Chapple), and a primary dysplasia of all the structures of the hip (Gill).

That muscle dysplasia may be a factor in the development of hip dysplasia can be deduced from the congenital dislocation of the hip seen in arthrogryposis multiplex congenita and intra-uterine muscular dystrophy (myodystrophia foetalis). In both of these conditions the muscles are fibrotic and do not keep pace with the skeletal development. The characteristic position of the limbs in arthrogrypotics is comparable to the fetal position of the limbs at three months and suggests an arrest of development and failure of rotation of the limb bud (Badgley).

Pathology of Congenital Hip Dysplasia

The actual pathology is extremely variable, depending on the degree of dysplasia of the hip structures, the age of the patient, and the treatment which has been administered. The lack of pathologic specimens of untreated infants' hips makes it difficult to evaluate the significance of the changes that have been observed in the head and neck, acetabulum, and capsular structures. Most of the literature on the subject has comprised descriptions of cases dying in infancy and childhood, but after various forms of treatment which undoubtedly modified the primary pathology. Excellent descriptions of the pathology in the living subject have been written by Hey Groves, Colonna, Gill, Howorth, and many others, after having exposed the hips at open operation; however, few of these were untreated cases. There is also the inherent difficulty of evaluating completely the pathology of all the hip structures at open operation, the surgeon being limited by the confines of his operative exposure as well as his method of observation and his special interests.

In the early days when congenital dysplasia of the hip was not recognized until actual dislocation had taken place, and often not until the patient had reached the age of six years or more, there was an orderly pathologic process taking place from the dysplastic stage without subluxation, through subluxation, and then dislocation, and the structures of the hip became modified or distorted, depending on the extent of the original dysplasia and the forces acting on the hip throughout growth and development It is easy to understand why Hey Groves found little change in the head of the femur and a typical hourglass deformity of the capsule up to the age of two and a half years It is readily understandable, too, that if the dysplasia had been recognized in early infancy or childhood and treated by vigorous manipulation and immobilized with the head partly out of the socket, certain abnormalities, including flattening, wedging, and grooving of the head, would have resulted, and that the capsule would often have become flattened and fixed to the side of the ilium, thereby losing its typical hourglass deformity. The extent of damage to the structures of the hip after even a single manipulation may be such as to make further evaluation inaccurate, especially if the hip has been retained in plaster for a considerable length of time Allison has given us an excellent account of the pathology in a congenitally dislocated hip after manipulative reduction. He found evidence of severe trauma which even involved the obturator

bone in the development of the contour and position of the acetabulum. Torsion of the neck, therefore, would seem to depend on the rotation of both the lower limb and pelvis. Consequently any "arrest in rotation" of the limb bud must concern both the innominate bone with the spine as its axis and the lower limb with the hip as its axis, and each of these is concerned with the development and activity of the muscles which support them

Bomfin showed the close relationship between congenital hip dysplasia and congenital clubfoot. He reported that of 364 cases with a primary diagnosis of preluxation of the hip, 55 per cent had associated clubfoot, and of 500 cases with a primary diagnosis of clubfoot, 39 per cent had associated hip dysplasias. He believed that congenital clubfoot was caused by an embryologic arrest of rotation of the fetal limb. This observation and the close relationship between these two congenital abnormalities strongly suggests that failure of rotation of the fetal limb bud is also the cause of congenital hip dysplasia with a resultant subluxation

Le Damany gave considerable importance to the plane of the hip socket and its importance in the development of the hip. According to him, the plane of the opening of the hip socket in birds and animals is horizontal and the neck-shaft angle of the femur is perpendicular to it. This relationship corresponds to the development of the human fetus of four months. In humans at birth the plane of the opening of the socket is decidedly anterior owing to a greater development of the posterior acetabular rim This brings the posterior surface of the neck in close contact with the posterior rim of the socket, and an increasingly greater portion of the anterior surface of the head is not firmly engaged in the socket. If an abnormal degree of anteversion is present or if the neck-shaft angle is greatly increased, no part of the head could possibly remain in the socket, and anterior dislocation would be inevitable. But even in this event by simply flexing the thigh the head of the femur is directed upward, inward, and backward, and thereby returns to its position in the socket. Le Damany states, therefore, that because the position of flexion is the fetal position, "dislocation has no reason to occur in flexion." In a position of extension, however, the posterior surface of the neck strikes the acetabulum and the head is levered out of the socket. With constant pressure, the posterior rim atrophies and becomes shallow and therefore cannot retain the head. As a result of this abnormal pressure of the posterior surface of the neck on the posterior rim of the socket, the blood vessels in the retinaculum of Weitbrecht are also compressed, producing a relative decrease in the blood supply of the nucleus of the head as well as the metaphysis, and this decrease may in part account for the hypoplasia of the neck and head so characteristic of hip dysplasias The interference in the blood supply may also cause some softening of the metaphyseal junction and thereby play a role in the increasing anteversion.

Murk Jansen believes that the hip dysplasias are all primarily caused by the extreme development of the brain in man which necessitates a wider pelvic girdle to secure birth. The wider the pelvic girdle the more complicated the processes required for stability in erect ambulation.

One of the oldest theories is the forced position of the fetus *in utero*. It probably does account for an occasional case, such as that reported by Chandler, and it may contribute to the deformity in others, but the majority opinion does not support it. Other theories include failure of development of the acetabular epiphysis

MARKED PREPONDERANCE OF CONGENITAL HIP DYSPLASIA IN GIRLS

Since about 85 to 90 per cent of congenital dysplasia of the hip with or without dislocation occurs in girls, they may rightly claim almost an exclusive right to this affection. Stewart kindly explains this marked predominance in girls by their higher stage of ontologic development in that "their monoembryonic pelvis has departed farther from the more primitive or polyembryonic pelvis of the male." Le Damany has another explanation. He states that newly born boys have a pelvis broad above and narrow below because of the coming together of the ischia—the result being that the acetabulum is directed strongly downward, which gives the femur a good support. In girls, the opposite is true—the subpubic angle is widened, the ischia are more separated, and the acetabulum is more vertical. It is possible that sex differentiation may play a part in the embryologic rotation of the limb bud to form either a male or female pelvis, development of the latter being such as to make dysplasias more likely to occur. Kingsley and Olmsted report a higher degree of anteversion in the female, and this could be explained on the basis of a relatively greater rotation of the lower extremity than of the innominate bone. In his study, Howorth found differences between the male and female pelves which were comparable to that in the adult, but none which would account for the preponderance of congenital dysplasia of the hips in females. Wernsdorf's observation that females are preponderantly involved because the hip socket in the female develops more to the side, whereas the male's is turned to the front could also be explained on the basis of a relative retardation of, or difference in, rotation of the innominate bone in the female. If this normal relative retardation in rotation of the innominate bone is combined with any degree of hypoplasia, either skeletal or muscular, the incidence of hip dysplasia in girls appears the more plausible.

DIAGNOSIS OF HIP DYSPLASIA WITH OR WITHOUT DISLOCATION

It is generally agreed that the sooner the dysplasia is diagnosed and treated the better the chance for a perfectly normal hip. The ideal would be to recognize the condition at birth and direct the activities of the infant to assist in the remodeling processes of the hip Perhaps in this way the development of a true dysplasia with luxation could be prevented in many instances. The diagnosis, however, is extremely difficult in the newborn because of the many normal variations at birth and the fact that the head and acetabulum are mainly cartilaginous. Even in clinics where routine examinations for dysplastic hips are carried out, the diagnosis is frequently not made until the age of three or four months or later, when the upper femoral epiphysis begins to ossify. Dysplasia of the hips should be suspected in every infant born with a clubfoot because of the frequent association between the two conditions, as shown by Bomfin.

In the first few months of life the condition is practically always a simple dysplasia without dislocation and only a mild or moderate degree of subluxation, which makes early diagnosis, especially in bilateral cases, all the more difficult. If the condition is present on one side only and if the subluxation is sufficiently established, (1) the affected side may show a slight limitation of abduction; (2) the thigh may be a little more externally rotated, (3) there may be a slight de-

nerve. The anterior division revealed evidence of swelling, fibrosis, interstitial neuritis, and degeneration of axis cylinders, many of which showed no medullary sheath whatsoever. *It is to be expected, therefore, because the diagnosis of congenital hip dysplasia is now usually made in infancy when the processes of remodeling of the hip are so active and sensitive, and because open reduction is usually not resorted to until after a trial at conservative therapy, that future reports of the pathologic anatomy of hip dysplasias will be at variance with the* usually accepted statements in our textbooks and literature.

Types of Dislocations

Although there is general agreement concerning the classical posterior and the upward dislocation or subluxation, there are many who question the existence of a true anterior dislocation. Others consider it of little importance because the position of the head in relation to the socket may change constantly, depending on the position of the thigh and other factors. In a study of 100 operative cases, Howorth found that the head was dislocated outward, upward, and forward, and that posterior dislocations were few and almost uniformly occurred in older children. Badgley, however, states that anterior dislocation is infrequent and is always accompanied by coxa valga and anteversion. According to Krida, the primary displacement is anterolateral, the secondary displacement is frankly lateral, and the terminal state is a posterior dislocation which rarely manifests itself before the end of the third year. Like Le Damany, he points out that the anteriorly displaced head rotates into a posterior position on flexion of the thigh, confirming the former's belief that the fetal flexed position is incompatible with dislocation in the early stages of dysplasia. Stewart is also in accord with the mechanism of dislocation described by Le Damany and with the views of Krida in his statement "a high degree of anteversion and a well developed ischial acetabular rim are incompatible with retention and result in anterior displacement." *From these observations it seems reasonable to conclude the primary position of the head in relation to the plane of entrance into the socket is anterior, and that this position with varying degrees of lateral and upward displacement is retained until actual dislocation takes place, when the head usually shifts into a posterior position.* In the unusual case, depending on the rotation of the limb bud and the degree of angulation and torsion (retroversion) of the neck, the primary position could be developed posteriorly, or the head might shift forward from its original anterior position (probably due to a relaxed or poorly developed anterior capsule) to a position under the anterosuperior iliac spine and thus produce the so-called primary anterior dislocation. The latter is considered to be a distinct clinical entity by McCarroll and Crego in a report of 10 cases. The position of the head under the anterosuperior spine is comparable to that in which the head was forced there by the "anterior reposition" operations of Lorenz and others.

In Chandler's unusual case in which the dislocation probably occurred in intrauterine life, there was a bilateral posterior dislocation with 20° retroversion of the neck. A similar amount of retroversion of the neck was present in Allison's case. In Schede's 2 specimens there was also retroversion instead of anteversion of the neck. The primary position of the head in relation to the opening of the socket could be considered to have been posterior in all these cases.

the anterosuperior iliac spine and the tuberosity of the ischium). In bilateral cases there is a characteristic widening of the perineum (probably due to incomplete inward rotation of the limb bud). In unilateral cases this is often manifested by a unilateral distortion of the bones of the pelvis. The acetabular angle (the angle

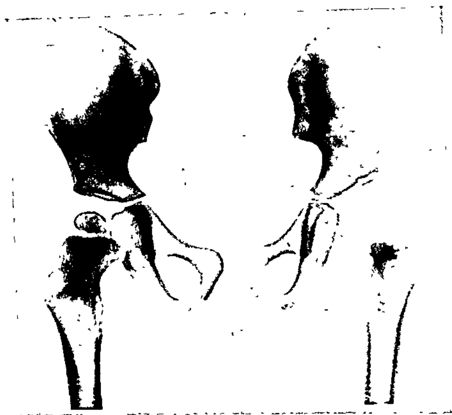


Fig. 8 —Roentgenogram of a congenital subluxation of the hip to demonstrate Putti's diagnostic triad, which is (1) delayed appearance of the osseous capital epiphysis, (2) increased distance of the trochanter from the acetabulum, and (3) abnormally steep or short acetabular roof.

between the roof or iliac portion of the acetabulum and a horizontal line passing through the Y or triradiate cartilages) can be measured and is usually found to be increased to 30° or more (the normal being 20°) (Fig. 9). Kleinberg and Lieberman state that if the angle in an infant is 30° or more, dislocation will probably occur Concerning the importance of the abnormally steep or short acetabular roof of Putti's well known triad, Hart states that the primary roentgenographic feature of dysplasia of the hip is an increase in the angle of incidence of the roof of the socket and that this angle is increased to 30° or more in dysplasias. Shenton's line is always irregular and the neck of the femur shows varying degrees of shortening and widening (Fig. 9). The interpretation of lateral views of the hips is less difficult at this stage and the recognition of bilateral cases facilitated Bruce's measurements may be used to determine the existence of, or extent of, subluxation. A horizontal line is drawn on the film through the clear areas in the center of the acetabula which represent the triradiate cartilage, and a vertical line is drawn through the edge of the acetabular roof. In unilateral subluxation the vertical line is drawn on the sound side, and a parallel line equidistant from the

crease in the normal flexion contracture of the hip which is present at this age, (4) there may be an increase in the number of, or a deepening of, the folds in front or back of the thigh; (5) there may be an apparent shortening of the thigh on the involved side; (6) there may be a slight looseness of the joint determined by *moving the flexed thigh up and down on the fixed pelvis; (7) the pulsation of* the femoral artery may be less distinctly palpable on the affected side if the head is abnormally placed and therefore does not support the vessel (Fig 7); and (8)

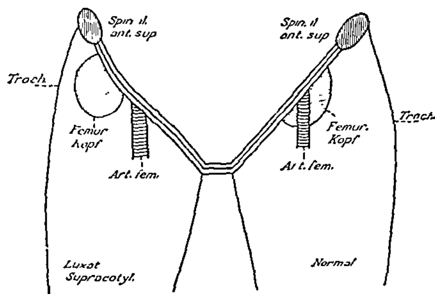


FIG 7.—Schematic drawing of the position of the femoral head in relation to the femoral artery and Poupart's ligament Normally the femoral artery is in front of the femoral head and the latter gives it support on palpation If the head of the femur is displaced, the femoral artery loses its support and cannot be palpated or the pulsation may be less than that on the normal side

there may be a slight lateral bulge of the greater trochanter when the flexed and externally rotated thigh is brought to an adducted position. Roentenologic examination will often show only a slight hypoplasia or abnormality in the shape of the pelvis on the affected side, but frequently there is evidence of an abnormally steep socket or shallow roof or a slightly laterally placed upper femur. Slight variations in the roentgenograms are difficult to evaluate in an infant due to the flexed position of the hips and the technical difficulties in obtaining true projections.

DIAGNOSIS OF HIP DYSPLASIA WITH SUBLUXATION AT THE TIME OF APPEARANCE OF UPPER FEMORAL EPIPHYSIS

The diagnosis can usually be made at this time because postnatal growth and development have proceeded to a stage where both clinical and roentgenologic findings are no longer presumptive. Actual dislocation, however, is seldom present, and the condition is usually one of hip dysplasia with subluxation Putti's diagnostic triad can almost always be demonstrated, i e, (1) delayed appearance of the osseous capital epiphysis, (2) increased distance of the trochanter from the acetabulum, and (3) abnormally steep or short acetabular roof (Fig. 8). The previously noted dysplastic findings become more pronounced, and the greater trochanter can usually be found to lie above Nélaton's line (a line drawn between

does not occur until the child begins to walk. The presumptive findings in infants with minor luxation and the more positive findings at the time of ossification of the capital epiphysis continue to become increasingly magnified until actual dislocation occurs, at which time it is usually possible to make an accurate diagnosis by a careful physical examination alone.

DIAGNOSIS OF HIP DYSPLASIA WITH DISLOCATION BEFORE THE WALKING STAGE

The findings in dysplasia with dislocation before the walking stage can be briefly summarized as follows: (1) The increase in or deepening of the skin folds or creases is more prominent (Fig. 10). Usually the inguinal crease is deepened

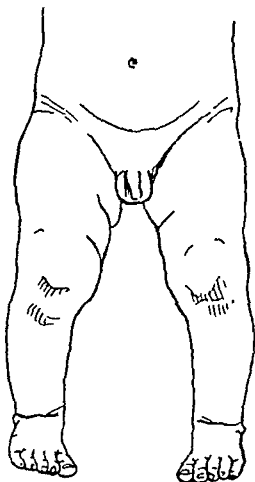


FIG. 10.–Sketch of a newborn infant with the legs placed parallel. Note on the right side fullness in the greater trochanter area and two skin inner thigh creases contrasted with a similar more shallow thigh crease on the left. These findings are always suggestive of a right congenital hip dislocation.
(After Freiberg)

on one side in unilateral dislocation and on both sides in bilateral cases. There are usually two or more creases or folds on the posterior aspect of the thigh on the involved side, whereas normally there is usually only one. (2) There is a palpable absence of the normal "fullness" of the anterior aspect of the hip and a palpable absence of the head from the acetabulum. (3) The pulsation of the

midline is drawn on the affected side. Normally the capital epiphysis lies below the horizontal line and medial to the vertical line. In potential dislocation or subluxation it lies below the horizontal line but lateral to the vertical line (Fig. 9), whereas in actual dislocation it lies above the horizontal line and lateral to the vertical line (Fig. 9)



dislocation. The horizontal line has been drawn through the clear areas in the center of the *acetabula which represent the triradiate cartilage The vertical lines are drawn through the* edges of the acetabular roof The acetabular angle on the dislocated side (A) measures 37° (normal 20°)

European writers (Leveuf, Severin) have suggested the value of arthrographic studies of the hip as an aid in diagnosing the exact pathology present These arthrograms reveal the outline of cartilaginous structures which are not visualized by direct x-rays, as well as the relaxation of the capsule The procedure has not had wide acceptance in this country and is usually not recommended as a safe or necessary diagnostic aid.

Diagnosis of Hip Dysplasia from the Appearance of the Osseous Capital Epiphysis to the Walking Stage

During this stage of the growth and development of the hip, the incidence of dysplasia with dislocation begins to increase, but in most cases actual dislocation

anteroposterior views of the pelvis with the patella straight up as well as with the thighs in maximal internal rotation, *in order to determine* the approximate degree of anteversion of the neck and to note whether the displaced head will approximate the socket in this position. *Routine films should also include* "push and pull" views of the pelvis to determine the extent of laxness of the capsule and whether the head comes down to or below the level of the acetabulum *on pulling. Because* of the relative frequency of bilateral hip dysplasia and especially of dysplasia without dislocation, it is necessary to examine the opposite side carefully *in every* case of unilateral dislocation, not only at the time of the original examination but also during the entire treatment of the dislocated hip. Sometimes a hip dysplasia is not recognized until there is an actual dislocation of the opposite side.

Diagnosis after the Walking Stage

It is after the walking stage that in most instances the extent of dysplasia of the hip is revealed, and an increasingly greater proportion of cases begins to show dysplasia with dislocation. True dislocation, however, may not become manifest *for several years*. In addition to the clinical and roentgenographic findings in the dislocated hip before the walking stage, the advent of erect posture and ambula*tion produces still further signs of hip instability* and dysplasia, the most important being the abnormality in posture and gait, and the positive Trendelenburg *sign. There is usually an increase in the lumbar curve which is more pronounced* in the bilateral cases. The gait is typically "waddling," either unilateral or bilateral, because *when the child puts her weight on the affected side the head of* the femur rides up on the ilium and the gluteal muscles cannot exert their stabiliz*ing influence. This also produces a positive Trendelenburg sign. The sign is con*sidered positive when the child stands on the affected extremity and the opposite crest of the ilium and gluteal region fall instead of rising, owing to inability of the gluteus medius of the affected side to stabilize the pelvis (Fig. 12).

As the child grows older and approaches the age of two the waddling gait may have a tendency to decrease, the lumbar lordosis may become more prominent, and the telescoping less marked. The head and acetabulum may show marked deformity owing to the demands of function in their abnormal relationship. After the age of six there is a progressive deformity of the head and acetabulum, and the latter may show nothing more than a slight indentation. At this time the patient may first complain of some pain and fatigue.

Diagnosis of Primary Anterior Dislocation

Although some orthopedic surgeons believe that such an entity does not exist, most texts include it as a distinct type of dysplasia of the hip. Royal Whitman states. "The symptoms of unilateral anterior dislocation, in which the head lies beneath the anterosuperior spine, are much less marked than in the classical posterior dislocation because the relation of the pelvis to the femur is more nearly normal. The shortening and limp are less marked because of the relative secure support offered by the tissues inserted in the anterosuperior spine. The lumbar lordosis is usually normal or even flattened." McCarroll and Crego regard primary anterior congenital dislocation of the hip as a distinct clinical entity and state that it can be accurately differentiated from posterior and upward dislocation by the

femoral artery is less distinct on the affected side because the head does not support the artery as it is being palpated (4) There is an absence of the normal infant flexion contracture of the hip with the head out of the acetabulum. (5) There is a definite limitation of abduction of the thigh on the affected side, bilateral in bilateral cases, whereas all the other motions of the hip are usually increased. (6) The leg will be in a position of external rotation because of the dominant action of the external rotators with the head out of the socket (7) In unilateral dislocation there is an apparent shortening of the thigh on the affected side as evidenced by the lower position of the knee with the patient in the recumbent position with the knees and hips flexed and the soles of the feet square on the table (Fig. 11).

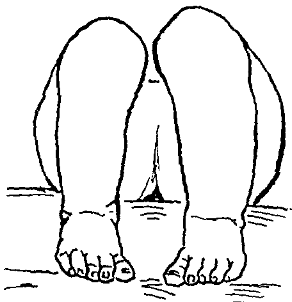


Fig 11 —Sketch of a newborn child with a congenital dislocation of the right hip The difference in leg length is difficult to determine at this age with the tape line With the child on its back, the knees and hips moderately flexed, and the feet held parallel and together, shortening is demonstrated by the difference in knee levels, the right being lower, indicating a shortening of the right leg.
(After Freiberg)

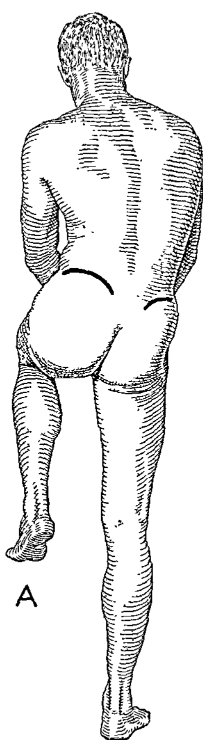
This test cannot be used in bilateral dislocations. (8) The telescoping sign is always positive, as evidenced by the abnormal piston-like motion of the greater trochanter as the thigh with bent knee is forced up and down on the stabilized pelvis. This sign becomes more pronounced, however, after the child begins to walk (9) The greater trochanter always lies above Nélaton's line. (10) The head of the femur may be palpated posteriorly. The roentgenographic findings will not only show the hypoplasia of the pelvis, the relative hypoplasia of the capital epiphysis, the irregularity in Shenton's line, and the steep acetabular roof, but also the position of the head in relation to the socket, and the degree of dislocation. Bruce's measurements can be used for this purpose and will show the capital epiphysis to be above the horizontal line and lateral to the vertical line; however, good lateral views are necessary to show the relationship of the head to the acetabulum in the lateral plane. Roentgenographic studies should also include

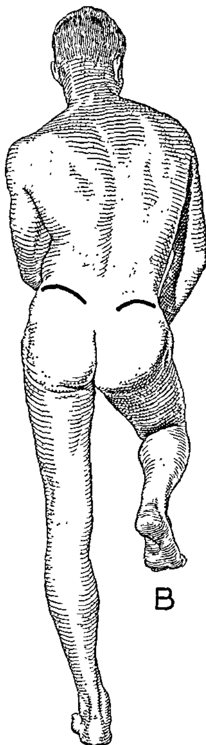
following: (1) *lumbar lordosis absent*, (2) less shortening, (3) buttock flatter, (4) anterior bulge just below anterosuperior spine, (5) femoral head palpable just below anterosuperior spine, and (6) lateral roentgenograms show a true anterior dislocation.

TREATMENT OF CONGENITAL DYSPLASIA OF THE HIP

Historical. Since the time of Dupuytren when congenital dislocation of the hip was first recognized as a distinct clinical entity (1828), there has been a continuous debate on the *fundamental issue of* "closed versus open reduction" as the method of choice in treatment. As early as 1830 Humbert performed an open reduction, and it was not until 1888, 58 years later, that Paci first reduced a congenitally dislocated hip by the closed method. Paci's work was so stimulating that seven years later in 1895 Adolph Lorenz and Albert Hoffa were able to report a large series of cases treated by the closed as well as the open method. Paci's manipulative reduction was the basis for the famous "bloodless operations" of Lorenz, which caused the latter to be invited to the United States at the turn of the century to demonstrate his method. Shortly thereafter report of the works of E. H. Bradford, G. G. Davis, John Ridlon, Harry Sherman, R. A. Hibbs, and others appeared in the literature, which for the next 20 years assumed voluminous proportions. The wide diversity of opinion resulting from this work could be best expressed by the views of the following men: Galloway, who recommended open reduction in all cases, in 1926 wrote. "The operative results in young children are so uniformly satisfactory that one no longer approaches these cases with a feeling of dread or uncertainty, but with confidence that the treatment is simple, safe and practically certain to result satisfactorily... this applies particularly to children under three years of age who have never been subjected to treatment by manipulation or otherwise." Allison in 1928 had this to say: "The surgeon who is called upon to treat congenital dislocation of the hip must face the facts which have accumulated in the past 25 years, the period in which the treatment of this lesion has seen its highest development. An analysis of these facts will show that our present methods of treatment call for improvement. Any degree of complacency regarding the end results of treatment is untenable, untenable because the results show about 50 per cent success in double cases and about 60 per cent success in single cases, reduced well within the age limits."

In the same year Hey Groves, reporting a new method of operative treatment, concluded: "I can only express my firm conviction that all cases of this deformity are amenable to cure or alleviation Although it is quite true that if all cases came for diagnosis and treatment in early infancy, there would be little need for open operation, yet this ideal is probably a long way off, and in the meantime I am sure there is no justification for the common attitude of pessimism about the cases older than three or four years, most of which can be cured or relieved." Just one year later, in 1929, V. Putti, whose rich experience is generally recognized, held this rather optimistic view: "The technique now used for closed reduction has attained such a degree of perfection that I believe very little can be done to improve it and little is to be hoped from possible modifications." Our bibliography is replete with the names of those who have been outstanding contributors to the subject since 1930. These contributions have included improvements not only in





of the abductor muscles
(After Shands)

cation thereof, reduction may be obtained by gradually bringing the thighs into a position of maximal abduction and internal rotation, after which the position is maintained by apparatus suitable to the individual case. If the normal flexion contracture of the hip is still appreciable, care must be exercised in bringing the hip into the extended position. When a plaster spica is used, therefore, the thigh should be flexed as well as abducted and internally rotated. After two or three months with plaster immobilization, it may be possible to resort to a Dennis Browne splint (Compere and Schnute) or a similar spreader bar. By this method rotation of the limb is controlled, the spreader bar maintains wide abduction, and continuous pressure of the head in the socket is obtained without rigid immobilization. The infant is able to flex and extend his hips, sit up, or even stand, all of which are important in reshaping the socket and restoring hip function. In these cases the ligaments of the knee should be carefully watched because

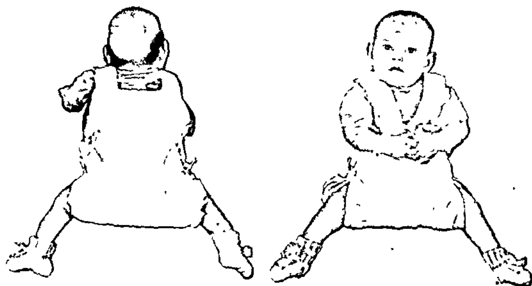


Fig. 14 – Frejka's pillow splint
(Courtesy of Dr. Vernon Hart)

of the danger of relaxation due to excessive mechanical strain, especially if the hips are not freely mobile in extension and abduction. Bilateral long leg casts with crossbars can be used for the same purpose (Fig 15). The casts extend to the upper thighs and the knees are bent so as to permit internal rotation. This position is safer in that it aids in protecting the ligaments of the knee joint.

Dysplasia with Dislocation. The ease of reduction and adequacy of retention are dependent not only on the extent of the pathology of the dysplasia but especially on the pathology produced by previous treatment. In a previously untreated case under 18 months of age the reduction is usually easily accomplished by simple manipulation following preliminary skin traction. However the growing epiphysis of the head may have been so severely injured and deformed by previously ill advised treatment, that reduction is not possible even with open operation.

operative and conservative technics and methods of earlier diagnosis, but also in the basic studies of the embryology and pathology of the condition, on which good treatment must depend.

Principle of Treatment of Congenital Hip Dysplasia. The general principle of treatment could be expressed as follows: early recognition, accurate atraumatic reduction, and uninterrupted retention of the head within the socket until a normal acetabulum has been developed, keeping in mind the prerequisites of motion as well as position for the proper remodeling and functional restoration of the hip joint

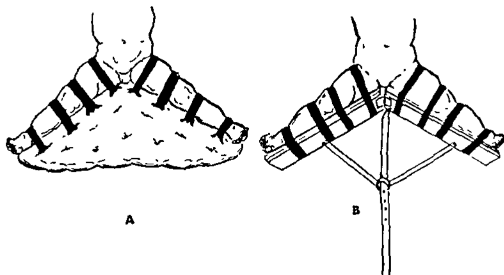


FIG 13—(A) Putti's mattress splint. (B) Putti's adjustable splint (After Mercer)

Treatment in Early Infancy (Before the Appearance of the Capital Epiphysis). In the first few months of life the displacement is so minimal that it suffices to place the normally flexed infant's thigh in slight abduction to obtain reduction. If this position is maintained for a few months, the reduction will be permanent (Putti) Putti's wedge-shaped splints (Fig. 13) or Frejka's pillow splint (Fig. 14) may be used for this purpose, or plaster leg casts with crossbars, or shoes with a crossbar. The thigh should not be forced into extension because the normally contracted iliofemoral ligament has a tendency to redislocate the head when it is stretched (Le Damany; Chandler; Allison). Transition from the normally flexed fetal position of the hip to that of extension should, therefore, be a gradual process and traumatic incidents tending to force extension should be avoided.

The Treatment in Late Infancy (from the Appearance of the Capital Epiphysis to the Walking Stage). In late infancy, the normal development as well as the dysplasia has usually progressed to a point where more direct treatment measures may be required. Dysplasia with subluxation is the rule, but actual dislocation may already have developed

Dysplasia with Subluxation: The great majority of these cases (94 per cent, Scaghetti) will develop normally if simply placed in abduction and internal rotation for a few months. With Putti's wedge-shaped splint (Fig. 13b) or a modifi-

ducted position, an audible *dull snap is* elicited as the head glides into the socket.

Method Described by Jones and Lovett: With the child on its back, the opposite thigh and pelvis are fixed by an assistant. The affected thigh is flexed to a right angle, internally rotated, and then abducted without losing the flexion or rotation. During this maneuver upward pressure is exerted on *the trochanter.* After reduction, the soft tissues in front of the hip are gently *stretched* so as to bring the knee in the same plane as the body. Stability is then tested by releasing pressure on *the limb and noting* the angle at which the hip redislocates.

Regardless of the method used, the objective of treatment is not reduction alone, but *reduction without trauma.* Allison expresses it this way: "Unless the dislocation can be reduced with what Lorenz called 'playful ease,' it had better be protected against the trauma of forced reduction." That aseptic necrosis of the femoral head should occur during the course of treatment of congenital dislocation of the hip in 25 per cent *of cases (Howorth), intimates* a lack *of appreciation of the validity of this principle of* atraumatic reduction.

Method of Retention. After accurate *atraumatic* reposition of the head in the socket, it is necessary to hold it there uninterruptedly until an adequate acetabulum has been formed and a stable hip assured. This may be accomplished in many ways, but the most popular method still is the "frog leg" plaster of paris cast originally devised by Lorenz (Fig. 16). In this position, the hip and knee are flexed to 90°, and the *thigh is abducted to 90° and externally rotated to 90°, the so-called 90-90-90 position.* The frog leg position has been used successfully for more than a half century, and therein probably lies the explanation for its continued popularity. Recently, however, there has been a tendency to question the advisability of this position, mainly because the surgeon who exposes the hip at open operation finds that he cannot retain the head in the socket in this classic position but *is usually required* to abduct and inwardly rotate the thigh, often to an extreme *degree, to maintain reduction.* Allison has given us a detailed anatomic study of the hip of a child who died four months after manipulative reduction and immobilization in the frog leg position. He found that the *pubofemoral ligament is tightened to its maximum as abduction is increased to 90°* as in the frog leg position, and *presses the head against the posterior rim of the acetabulum.* The pubofemoral ligament also acts as a pivotal point about which the femur swings as the head *is lifted into the socket by* upward pressure on the trochanter. The *iliofemoral ligament,* on the other hand, is *relaxed in the flexed position of the hip;* and on abduction the head passes forward and under this band. In the position of 90° flexion and 90° abduction with the head reduced, the *iliofemoral ligament is well external to the head and greatly relaxed.* It therefore has no influence on reduction after the Lorenz method. In Allison's case, however, the neck was retroverted about 20°, so that accurate appraisal of the effects of a tightened pubofemoral ligament on the anteverted head *is not possible.* However, *it is* possible that *this ligament is primarily responsible for keeping the head in the socket, and when it is damaged or cut as in open operation, the head cannot be contained in the socket in the frog leg position.*

Immobilization in the frog leg position is usually maintained for about three to six months, after which the leg *is gradually brought down to a neutral position* by

Methods of Reduction. Since the original method of Paci, there have been many minor modifications in the manipulative reduction of congenital dislocation of the hip, i e., Lorenz, Lange, Calot, Denucé, Ridlon, Davis, Le Damany, and others. Ridlon's method, for instance, differs from Denucé's only in that he does not use preliminary massage of the adductors to obtain relaxation prior to reduction. Jones and Lovett and Le Damany use essentially the Paci-Lorenz method and they too disapprove of preliminary massage of the adductors Davis' method



Fig 15.—Bilateral long leg plaster casts with the hips held in abduction and internal rotation by means of cross bars This is used as a means of postreduction fixation in certain instances. (After H R McCarroll)

differs mainly in that the reduction is performed with the child in the prone position. Most orthopedic surgeons today use either the Denucé method or some slight modification of the Paci-Lorenz procedure which has proved most effective in their hands

The Denucé Method: After preliminary stretching of the adductors by abduction and massage, the thigh is flexed on the abdomen and circumducted from the opposite axilla around the involved side while at the same time upward pressure is exerted on the greater trochanter As the thigh is brought around to the ab-

successive changes of casts for another three months. After six to nine months, the legs are maintained in wide abduction and internal rotation by means of splints or braces until a functional joint is assured. Many continue the frog leg immobilization for six months and then gradually change the position of the leg for three more months. Some even advocate plaster immobilization in the original position for eight to nine months (Brewster). The period of immobilization in plaster recommended by Putti is much shorter. He uses the frog leg position for only one and a half or two months and then gradually brings the legs into extension and internal rotation and holds them there by special splints, *stressing the necessity of function of the hip during the period of immobilization.*

Calot first determines the degree of anteversion of the neck and then immobilizes the hip in flexion and different degrees of abduction and internal rotation, depending on the angle of anteversion. He uses a position of hyperflexion of the hip to an angle of 45° for two months in the first cast, an angle of 90° for two months in the second cast, and 135° for two months in the third cast. The actual period of immobilization varies with the age of the patient.

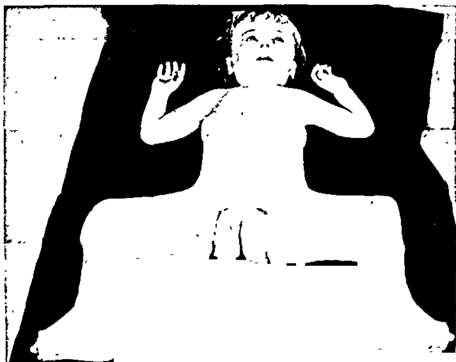
Werndorft employs a so-called "axillary abduction" position when the hip is very unstable. The knee is brought up practically into the axilla and held in this position for about six to 12 weeks, followed by the usual frog leg position.

McCarroll and Crego have long abandoned the classical frog leg position in favor of a position of abduction and internal rotation with the hip extended. A bilateral hip spica is applied which extends to the opposite knee. In certain cases they use bilateral long leg casts with crossbars to hold the legs in abduction and internal rotation while at the same time leaving the hips free for motion (Fig. 15). Their views are in accord with that of Lange who states that the hip should be immobilized in hyperextension, internal rotation, and abduction to about 135° because of the anteversion of the neck and the fact that this is the position required to maintain reduction at open operation.

Blount's "peg-leg cast" consists of immobilization in the Lange position, the cast being prolonged distally at the knee by means of a crutch incorporated in it in order to permit weight-bearing.

Compere and Schnute recommend the following plan of treatment: (1) frog leg position for two months; (2) abduction spica cast with leg in moderate internal rotation for two months; (3) bilateral casts to the lower extremities held widely apart by a plaster strut to maintain constant abduction and internal rotation for two months thus permitting the child to sit up and be somewhat active; (4) Denis Browne splint with long spreader bar for two months—the splint is removed each day for bathing, (5) spreader splint is left off for one hour twice daily, and each week an additional hour is added until the splint is left off entirely during the day. The splint is then worn as a night splint until the hip joint is normal.

All these methods have one thing in common, the continuous retention of the head within the socket. That this can be accomplished with good results in so many ways and with the extremities in such various positions is a tribute to the pliability of the human form at this age and the inherent forces of growth and development.



A



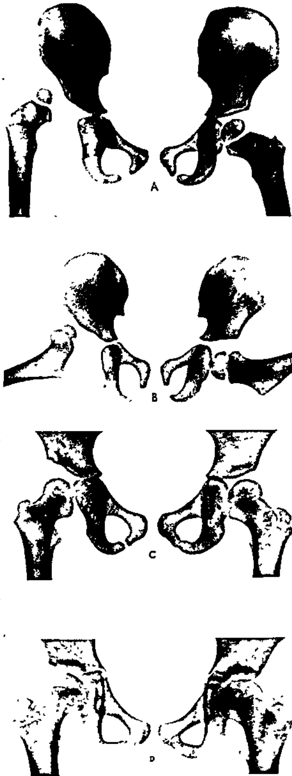
B

FIG. 16.—(A) Immobilization after reduction of a congenital dislocation of the hip in the "frog-leg" plaster of paris cast originally described by Lorenz. In this position the hip and knee are flexed to 90°, the hip is abducted to 90° and externally rotated to 90°. (B) Bilateral congenital dislocation of the hip in a "frog-leg" plaster of paris cast showing the child on a Bradford frame suspended by webbing straps from ends of crib. Note the bed pan beneath the frame.

Treatment after the Walking Stage. The treatment is the same as before the walking stage, except that reduction and retention are often much more difficult to achieve by conservative measures. At this stage it is usually necessary to resort to traction in order to bring the head down below the level of the acetabulum before atraumatic reduction can be accomplished. Depending on the degree of shortening of the capsular structures and the muscles, and on the age of the patient, varying amounts of traction are required. Ordinarily skin traction suffices, but sometimes it is necessary to resort to skeletal traction. McCarroll and Crego state also that as much as 15 to 20 pounds traction is often necessary even in young children, and that this amount of traction cannot be secured by skin traction.

Besides the shortened muscles and capsule which can be treated by preliminary traction, most authorities agree that a high degree of anteversion of the neck is one of the chief obstacles to a successful reduction. Treatment of this condition by some form of osteotomy is often done by the surgeon who performs an open reduction, but it is seldom done as part of the closed or conservative treatment. Schede (1897) was the first to recognize the importance of anteversion of the neck, and he proposed a plan of treatment which, with minor modifications, is being used by many of our leading orthopedic surgeons (J. Royal Moore). After reduction, the hip is immobilized in plaster for three months with the leg in abduction and maximal internal rotation. A derotational subtrochanteric osteotomy is then performed, fixing the upper fragment by means of a long nail. Postoperatively the hip is fixed in plaster for three months, incorporating the nail in the cast. It was not long after Schede's work that Lorenz discovered it was usually the excessive anteversion of the neck that produced the failures of closed reductions. Whereas Schede proposed a subtrochanteric osteotomy, others performed it in the supracondylar region either surgically (Hey Groves) or manually (Krida). Galeazzi recognized anteversion of the neck as the most important element in the dislocation and proposed exercises to correct it, after four months immobilization in plaster in the reduced position. Compere and Schnute state that the anteversion will correct itself in almost all cases without osteotomy. Gill was of the same opinion, on the basis of his experience with 75 open operations, when he said: "Anteversion of the neck which has been talked about by so many orthopedic surgeons has never presented any difficulty in operation, and in no instance has the writer been obliged to operate to correct this condition." Since an "abnormal" angle of anteversion of 35° is considered to be normal at birth and, since as the result of postnatal growth and development this angle gradually diminishes, it would seem reasonable to believe that an angle of anteversion greater than 35° would also be amenable to the same forces which normally derotate the femur. The advisability of complete correction by 90° of derotation, as is currently being recommended and practiced in some clinics would in this light appear to be questionable.

FIG 17.–(A and B) Anteroposterior and lateral roentgenograms of a congenital dislocation of the right hip in a three year old girl before reduction (C) Two years after successful closed reduction The acetabulum is still somewhat shallow but the head of the femur remains fitted well within the acetabulum (D) Seven years after successful closed reduction showing a well rounded smooth head and well developed normal acetabulum.



Caption on opposite page

contained in his admonition that "the plan of *operation should be made* with the avoidance of force as its most important feature. It does not necessarily hold true that force and resultant damage to *the growing epiphysis are lacking in* reduction by open operation." Because the diagnosis was seldom made before early childhood, operation in those days was rarely performed before the age of two. Today, however, an increasingly large percentage of cases come to *operation* before or shortly after the walking age.

Hey Groves (1928) and Colonna (1930) were the first to use the redundant "hourglass" capsule as an interposing tissue after enlarging the socket, the main difference being that the former secured the capsule intrapelvically by means of kangaroo tendon. Both stressed the necessity of preliminary traction to bring the head down below the level of the acetabulum. For the younger age group, Colonna originally recommended the procedure for patients under the age of three years whose hips had been satisfactorily reduced by the closed method but did not remain reduced. However, since that time, his procedure with modifications has been the treatment of choice with many orthopedic surgeons for most cases in which closed reduction fails (J. Royal Moore). Other surgeons simply expose the hip, divide the capsular attachments, and replace the head into the socket, or, if the socket is too shallow, it is first deepened. In older children if the head cannot be brought down to the level of the acetabulum or if the acetabulum is markedly deformed, the "shelf operation" of Gill or Dickson is recommended (Fig. 18). Good results following operation depend on the construction of an adequate shelf of bone to produce a functional roof over the head for stability. McCarroll and Crego recommend a wide shelf, extending from the superior rim of the acetabulum and including the anterior superior iliac spine, in the treatment of irreducible anterior dislocations. In their experience all anterior dislocations have recurred following closed reduction, even when preceded by skeletal traction.

THE DO'S AND DON'TS IN THE MANAGEMENT OF CONGENITAL DISLOCATION OF THE HIP

(1) Don't forget that the disorder is essentially a growth disturbance or dysplasia which may manifest itself either immediately after birth or not until the child begins to walk.

(2) Do keep in mind that although we speak of congenital *dislocation* of the hip we recognize the fact that there is also a *potentially dislocating* hip and a *subluxating* hip.

(3) Don't fail to make the diagnosis in its earliest stage, preferably soon after birth, and [illegible] the chance of [illegible] per cent.

(4) [illegible]

(5) Always suspect dysplasia of the hip in children born with clubfoot or other congenital abnormalities

(6) Don't forget to take roentgenograms in all cases which show slight clinical abnormalities in the hip and thigh regions If the child is less than four months of age, there may be only a slight variation in the acetabulum or a slight displacement *of the upper end of the* femur or a slight variation in the pelvic bones

(7) Remember that a good physical examination must include a careful inspection for abnormal skin crease [illegible] and for pulsation [illegible] n the anterior aspect [illegible] limitation of motic [illegible] shortening and mild

(8) Don't fail *to look for* Putti's diagnostic triad at about the age of four months or at about the time of appearance of the osseous *capital epiphysis* The triad consists of the following (a) delayed appearance of the osseous capital epiphysis, (b) increased distance of the trochanter from the acetabulum, and (c) abnormally steep or short acetabular roof.

THE OPERATIVE TREATMENT

Although open reduction was performed as early as 1830 (Humbert), it was not until 1926 that its advocates had the courage to recommend it in practically all cases of congenital dislocation (Galloway). About that time Allison expressed the view which has governed the indication for open reduction to the present time

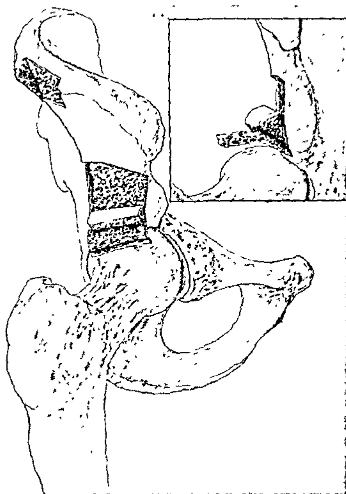


FIG
it is
ness

by a wedge of bone taken from the iliac crest
(After Shands)

in the following words "When closed reduction by the method of Denucé or
Davis is not easily acc
hip by open operation.
properly executed oper
all resistant cases to that of force, damage, and long periods of fixation without function That open operation in itself is not a guarantee against damage to the epiphysis or joint, such as would be expected from a forceful closed reduction, is

fact, the surface cartilage of the head is peculiarly uninvolved. Aseptic necrosis of the capital femoral epiphysis most nearly defines its essential pathology, but there is *a characteristic type of necrosis* in this disease which is distinguishable from that occurring in other conditions.

Historical

It is an interesting circumstance that the disease was first made known to the profession almost simultaneously by the three men whose names are so frequently used to designate it, i.e., Legg (Boston) 1909; Calvé (France) 1910, and Perthes (Germany) 1910. Waldenstrom (Sweden) also described it about the same time. Before then, the disease was usually considered to be a form of tuberculosis.

Age and Sex Incidence

It is a significant fact that coxa plana occurs almost exclusively in boys (85 to 90 per cent) and that this predominance in boys is exactly the reverse of that in congenital dislocation of the hip (Gill). Howorth reported a sex incidence of 85 per cent in boys, and Levy and Girard found 91 per cent involvement in boys in a review of 102 cases. It is equally significant that the age incidence is restricted to the middle childhood or permanent tooth period, between the ages of six and ten (Arey). Because the teeth are considered to be a part of the skeleton and the age of onset of the disease and beginning of permanent dentition correspond to the stage of development when for the first time since birth development of the female is not definitely in advance of the male (Arey), it is possible that certain variations in the growth of the head and neck of the femur are present in boys during this period which predispose them to coxa plana. The disease is unilateral in 90 per cent of cases (Gill; Howorth; Levy and Girard).

Etiology

The etiology of coxa plana is unknown, but the following theories are advanced to explain it: (1) vascular disturbance of the capital epiphysis; (2) infectious or inflammatory process; (3) trauma; (4) primary disturbance in the growth or dysplasia of the capital epiphysis; (5) a combination of the above factors; (6) hereditary and familial factors.

Vascular Disturbance of the Capital Epiphysis. Some form of vascular occlusion has been generally accepted to be the essential cause of this disease. The vascular occlusion may be the result of thrombosis, emboli, or spasm, or other factors, such as compression by an overly distended joint. Attempts to reproduce the disease in animals by occluding the vessels of the ligamentum teres as well as the vessels about the neck have been unsuccessful (Lippmann; Zemansky; Stewart). Lippmann and Zemansky occluded the vessels of the round ligament in rabbits and found a condition "closely resembling Legg-Calvé-Perthes disease." Stewart, in one group of rabbits and dogs, tied only the ligamentum teres, and in the second group also circumcised the vessels around the neck, and concluded that "no femoral head in animals with open epiphyseal lines showed changes similar to Legg-Perthes disease." A careful search of the literature failed to dis- close any animal experime [illegible] arteries had been tied off.

(9) Don't forget to begin treatment as early as possible, preferably early in the subluxation stage, and as soon as the diagnosis is made.

(10) Do remember that early in the disease reduction can be obtained by simply bringing the thigh gradually into a position of abduction and internal rotation with the hip in mild flexion. Later it may be necessary to use a special manipulative procedure.

(11) But in any case, *don't ever use force in your manipulation*, because you may easily produce damage to the delicate growing head of the femur.

(12) If you decide to use the Denucé or a modification of the Paci-Lorenz technic, do observe all the details of the manipulation and refrain from forceful stretching of the adductors to obtain relaxation.

(13) In any case, if the reduction cannot be performed without undue force, open reduction must always be considered

(14) Don't neglect to use *traction* as a preliminary step before reduction is attempted This is necessary in all cases with actual dislocation, but is also advisable in many cases of subluxation

(15) Don't discontinue the traction until the head has been brought down to or below the level of the acetabulum.

(16) Don't hesitate to use skeletal traction if skin traction is not adequate.

(17) Don't consider your reduction satisfactory until good AP and lateral roentgenograms show the head well placed in the acetabulum.

(18) Remember that permanent damage to the head and acetabulum will result if the unreduced position is maintained in a plaster cast for a considerable length of time

(19) Don't forget that the reduced position must be continuously maintained until an adequate acetabulum has been formed This will require at least six months in plaster followed by protective measures to keep the leg in an abducted and internally rotated position.

(20) Don't neglect to use as much functional activity as possible during the period of immobilization, and especially physiotherapy and muscle training exercises after the period of immobilization

(21) If you decide that open reduction is advisable, remember that the operation is simple only in the hands of a trained orthopedic surgeon and should never be attempted by the casual operator

(22) Don't attempt to prognosticate the final outcome and guarantee a normal hip, especially if the child has already been subjected to unsuccessful attempts at reduction.

(23) Remember that the statistics have not improved much in the past 20 years, and that unsuccessful closed reductions with redislocations average about 40 per cent, especially in bilateral cases, when followed over a period of years

(24)

(25) We are inclined to believe that almost all cases of actual dislocation are preventable if the diagnosis of the basic dysplasia is made early and proper conservative treatment is instituted

COXA PLANA

Synonyms

Legg-Calvé-Perthes disease, Legg-Perthes disease, Perthes' disease; aseptic necrosis of the capital femoral epiphysis; osteochondritis deformans coxae juvenilis

Terminology

Because the true nature of this disease is unknown, there is no completely satisfactory terminology. It is therefore often simply identified by the name or names of those who first described it as a distinct clinical entity. The term coxa plana, suggested by Waldenstrom in 1920, appears preferable because it describes the typical deformity (flattening of the head), which is characteristic of the disease. This deformity, however, need not always occur and healing may take place without a flattening of the head. The term osteochondritis is incorrect because there is not an inflammation of bone and cartilage (Gill); as a matter of

to the function of the thyroid gland (Gill). Schaefer and Purcell, on the other hand, state that the disease is due to hypothyroidism and should be called "juvenile osteochondral hypothyroidism." Cavanaugh, Shelton, and Sutherland studied five cases of coxa plana and found evidence of thyroid deficiency in all of them, colloid goiter in the mothers, maternal aunts, and other members of the family, retarded development of the bones of the hands, other stigmata of hypothyroidism, and rapid improvement on thyroid therapy. In discussing their paper, J. Albert Key remarked that he had been using thyroid therapy for many years but that he did not notice any difference in the course of the disease. Gill's studies on 20 cases indicate that there is no real evidence of thyroid etiology and that all types of the disease are not due to the same basic disorder or the same pathologic process. However, one is occasionally confronted with an atypical case, especially in girls with bilateral hip involvement, in which there is an apparent clinical hypoparathyroidism which cannot be substantiated by laboratory tests. Perhaps such cases are not true coxa plana.

A Combination of Any of the Above Factors. Although the basic cause of the disease may be an interruption of the blood supply of the capital epiphysis, any one or several of the other causes may act as contributing or predisposing factors. It is probable, too, that identical factors are not applicable in all cases, even though the typical massive subchondral necrosis of the head results.

The Hereditary Factor. It is generally agreed that there is no definite familial or hereditary factor in the disease, in spite of the reports of isolated cases which would tend to give credence to it. Coxa plana has been frequently reported to have occurred in the same family, and it has been traced through several generations (Brill). Hagan also found the astonishing incident of bilateral involvement in brothers, which would tend to support the theory that the condition is essentially a dysplasia or growth disturbance Others view the occasional familial tendency as a mere coincidence.

Stages of the Disease

The most characteristic feature of the disease is that it should occur in well defined and well recognized stages, and that these stages should progress through a period of about three to five years, the entire period of middle childhood. That the progression of the disease in time corresponds to that phase of the growth and development of the hip of middle childhood appears significant, because we are aware of no other disease condition that follows such a special pattern. Since the disease does occur in specific phases, we may well ask ourselves whether or not progression of the disease is inevitable once the initial pathologic process has begun We may well wonder, too, if there might not be variations in the disease (as in all other disease conditions) characterized by *less massive* degeneration of the head so typical of this disease It is generally agreed that coxa plana begins as a synovitis of the hip joint. If that is true, the subsequent changes in the metaphysis and the necrosis of the head could be regarded as complications of the synovitis, rather than an inevitable consequence of the disease process. A complacent attitude toward the inevitability of the progress of this condition therefore seems untenable, and invites the direction of our efforts to an earlier recognition and a better understanding of the incipient stage of the disease.

the profunda femoral artery and without entering the hip joint, so that the additional incisional and other trauma to the hip structures would not have to be taken into consideration We were also unable to find any evidence that coxa plana occurs in animals.

If our concept of the blood supply of the head and metaphysis of the neck of the femur is correct—that these areas are supplied by the medial and lateral circumflex femoral arteries, and that these arteries are end arteries during the growth period—it is easier to understand why vascular occlusion would result in the characteristic massive subchondral necrosis of the head as well as the changes in the metaphysis of the neck of the femur. It is interesting that in his experiments Stewart found absorptive changes in the neck of the femur when the periosteum of the neck was circumcised, and suggested that there are end arteries in the neck of the femur on its inferior aspect which had been injured at the time of operation.

Infection The adherents of the infection theory point to the fact that in many cases there is a febrile reaction which is sometimes rather marked, a mild or moderate leukocytosis, and an increase in the blood sedimentation rate. Phemister evaluated the infection theory from pathologic specimens and concluded that "histologically the majority of these lesions appears to have something more back of them than a simple embolus or injury cutting off the circulation and producing aseptic necrosis." Lippmann also found definite evidence of inflammation in a pathologic specimen. It is also possible that the inflammation of the soft parts, especially the synovitis, which is present in the early stage of the disease, may be due to some infectious process, the exact nature of which is unknown.

Trauma. As all hips are constantly being subjected to some form of trauma, it is difficult to evaluate its significance in the history or its effects. Trauma may be either in the form of a single acute injury or a succession of small or insignificant injuries, such as one experiences during normal activity. Necrosis of the head may be caused by the direct effect of this trauma, or indirectly by interfering with the blood supply of the head and neck. Trauma may also produce a synovitis which in turn causes vessel occlusion by direct pressure of the increased synovial fluid or as a result of inflammatory edema and thrombosis The advocates of the theory that trauma is the primary cause of the disease also point to the fact that aseptic necrosis of the head of the femur occurs in fractures of the neck of the femur in children, as a result of the slipping of the upper femoral epiphysis, and during the treatment of congenital dislocation of the hip. In these cases, however, the character of the aseptic necrosis is not the same as that observed in coxa plana (Gill, Brailsford) Although it is probable that trauma is not the primary cause of the disease, it may well play an important secondary role.

Primary Growth Disturbance or Dysplasia of the Capital Femoral Epiphysis. A primary growth disturbance or dysplasia of the capital epiphysis and metaphysis of the neck of the femur could result in necrosis of the head, or act as a contributing factor. The changes in form and dimensions of the hip which occur during this developmental stage are probably such as to make anomalies of the blood supply and metabolic disturbances apt to predispose the hips to vascular occlusion or injury resulting in necrosis of the head. The disease, however, is usually unilateral, and recent studies would indicate that there is no relationship

tion progresses, little or no evidence of a vascular system remains. The epiphysis disintegrates into many areas of dense necrotic bone surrounded by granulation tissue. Regardless of the extent of the degenerative changes in the epiphysis of the head, *the surface cartilage is not involved* and remains smooth and intact. The soft tissues are thickened, edematous, and inelastic. In Lippmann's case, the round ligament was enlarged and protruded stiffly from the fovea centralis, 12 mm. in diameter, red, markedly injected, and edematous.

The Third or Regenerative Stage. The dense necrotic areas are gradually absorbed by the granulation tissue and new bone is laid down by the process of "creeping substitution" of Phemister. This vascular granulation tissue contains polymorphonuclear leukocytes, small lymphocytes, plasma cells, and giant cells. The inflammation of the soft parts gradually subsides and the tissues return to normal. This is the pathologic picture of the so-called uncomplicated case.

The Fourth or Residual Stage This may not occur because the structures and function of the hip joint may return to normal or nearly normal unless complicated by such factors as lack of treatment or ill-advised treatment. Although it is sometimes admitted that the hip may return to normal even without treatment, and that its course cannot be modified by treatment (44th report of Progress of Orthopaedic Surgery, in *Archives of Surgery,* 22:857, 1931), the great majority of orthopedic surgeons today are in accord with the opinions of Danforth and Gill, that "the residual deformity is the result of weight-bearing on the softened head," and with Phemister's statement. "The characteristic feature of the carefully treated case is the absence of change in the articular cartilage and a return to normal function" The actual pathology of the residual stage depends on the extent of flattening and deformity of the head and adaptive changes in the socket, the deformity of the neck, the degree of scarring and thickening of the soft parts, and the integrity of the remaining blood supply

Symptoms and Diagnosis

The Early or Incipient Stage The symptoms and findings will depend upon the severity of the inflammation of the soft parts. Usually the first symptom is only a mild limp which may be present only on fatigue. If pain is present, the child may complain of it first in the knee and medial aspect of the thigh (distribution of the obturator nerve) or the pain may be referred to the groin. The pain is usually mild in character and sometimes entirely absent. It usually begins gradually and becomes aggravated by some trivial injury. Physical examination will disclose varying degrees of muscle spasm and limitation of motion of the hip. Since the pyriformis muscle and other rotators (gemelli and obturators) are intimately connected with the posterior capsule of the hip joint, any inflammation of the capsule will cause an irritation and spasm of this muscle group, resulting in a limitation of motion of the joint, especially in *internal rotation.* There is also a characteristic *limitation of abduction.* Palpation of the anterior region of the hip may reveal a palpable swelling of the joint (Gill's sign). Palpation of the posterior region of the hip, between the gluteus medius and maximus adjacent to the greater trochanter, is almost always painful, and is probably due to the spasm of the rotator cuff muscles and/or involvement of the hip joint. The onset and course in

There are certain inherent difficulties which present themselves, the principal ones being: (1) the depth of the joint which makes early clinical detection of swelling and pathology difficult or impossible; (2) the absence of early roentgenographic findings, (3) the lack of pathologic material, both post mortem and ante mortem during this stage, (4) the hesitation or reluctance to aspirate the joint or to expose the joint for biopsy and study in suspicious cases. Since these procedures are readily and often routinely performed for diagnostic purposes in cases of synovitis of the knee in childhood, it would seem proper in certain patients to do the same in the case of the hip, especially in view of the fact that the disease is expected to extend over a period of three to five years or longer, that the necessarily prolonged treatment is expected to have a profound effect on the patient as well as the family, and that in spite of treatment the child is liable to have a permanently disabled hip.

The stages of the disease are usually listed as follows: (1) incipient stage or stage of synovitis, (2) the stage of degeneration, beginning in the metaphysis of the neck and then involving the head; (3) the stage of regeneration; (4) the residual stage The first stage is said to last for several weeks, the second for one to one and a half years or longer, the third from two to three years or longer, with an abrupt transition between the stages of degeneration and regeneration (Gill). In a roentgenologic study of 121 cases, Brailsford was able to differentiate 12 different stages in the disease, but this highly specialized differentiation appears to be of only academic interest.

PATHOLOGY

There have been many contributions to our knowledge of the pathology of the disease, the most recent being a study based on 50 operative cases by Howorth, from which much of the following has been taken

The First or Incipient Stage. The pathology is confined to the soft parts. There is a synovitis, but the inflammation also extends to the capsule and periosteum. These tissues are swollen, edematous, and hyperemic, and the joint probably contains an increase in the amount as well as a change in the character of the synovial fluid Later there may be redundancy and villous formation of the synovial membrane The inflammation of the soft parts also includes the tissues in the region of the haversian gland, the so-called joint fat pad, the retinaculum of Weitbrecht, and the ligamentum teres No bony changes are observed in this stage.

The Second or Degenerative Stage The first changes occur in the neck of the femur on the metaphyseal side of the epiphyseal line. These changes are characterized by a softening due to decalcification and increased vascularity (Howorth), or they may result from inflammatory changes occurring in the synovial membrane and capsule around the neck enclosing the retinaculum of Weitbrecht which contains vessels supplying both the metaphysis as well as the epiphysis of the head of the femur The process of aseptic necrosis can therefore be considered to involve the metaphysis as well as the capital epiphysis (Gill) Some time after the involvement of the metaphysis, there is evidence of subchondral necrosis of the capital epiphysis. Dense areas appear in the head, the bone lacunae are empty, and the marrow is converted into a homogeneous mass. As the degenera-

PROGNOSIS

It is difficult to prognosticate the ultimate outcome of this disease because it is essentially self-limited with a tendency to spontaneous recovery. Healing, therefore, may take place even without treatment and with only minimal deformity and disability. On the other hand, with the best of treatment, the results are occasionally poor. Gill, however, struck a more optimistic note when he recently said: "When we are able to carry out Danforth's method of prolonged rest in bed without interruption, the end results are *practically perfect hips.*"

TREATMENT

The Early or Incipient Stage. Therapeutic measures should be directed at (1) absolute bed rest, (2) treatment of the synovitis; (3) relief of muscle spasm, and (4) treatment of the adduction and external rotation contracture. Almost everyone will agree that absolute bed rest, preferably with slight hip flexion, is necessary during this stage, but there is little agreement on the necessity for immobilization of the joint itself. In the 44th report of "Progress of Orthopaedic Surgery," *Archives of Surgery* (1931), the editors stated: "We question whether it is often necessary to employ immobilization even in the acute stage of this condition," and this opinion is still generally accepted.

Little or nothing has been written on the advisability of directing treatment at the synovitis in the first stage of the disease. Because the extent and seriousness of the swelling of the joint can seldom be ascertained clinically, it would seem desirable to aspirate the joint either anteriorly or posteriorly for diagnostic as well as therapeutic purposes. It would also seem desirable to determine the part that vascular spasm plays in the vascular occlusion and progress of the disease. This can be accomplished by the simple injection of a few cubic centimeters of 0.25 or 0.5 per cent procaine into the joint, preferably by the posterior route. If the synovitis is sufficiently severe, a few weeks of plaster immobilization may be indicated. Plaster immobilization should not, however, be prolonged (Howorth). The muscle spasm and adduction-external rotation contracture can be controlled by mild traction, preferably with the hip in slight flexion to relax the capsule and blood vessels. If warranted, the muscle spasm can also be alleviated by the injection of a few cubic centimeters of 0.25 to 0.5 per cent procaine directly into the posterior rotator cuff muscles of the hip. Local heat to the part in the form of superficial heat or diathermy may also be used.

The Second or Degenerative Stage (Fig. 19). Absolute avoidance of weight-bearing is important. Gill uses mild traction throughout this stage, not only for its local effect on the joint structures and muscles but also to ensure continuous bed rest. Danforth recommends either bed or wheel chair. Non-weight-bearing ambulation is permitted by the Fort or Snyder hip sling and crutches (Fig. 20), or by elevating the shoe on the sound side and crutches (Levy; Girard). Theoretically these methods appear sound, but practically it is almost impossible to keep the child from bearing weight on the affected extremity. Whereas Gill's method of continuous bed rest with mild traction during the entire active or degenerative stage seems drastic, it is probably the only way in which absolute avoidance of weight-bearing can be accomplished. In bilateral cases, bed rest and, or, wheel chair is the only effective method. The importance of a prolonged period of non-

the first stage may be accompanied by a febrile reaction which occasionally is rather marked. Ordinarily, however, there is only a subfebrile reaction. Roent-

luxation of the head from the socket as a result of the inflammation and swelling of the synovial membrane, haversian gland, and ligamentum teres. Except for an occasional mild leukocytosis and a mild or moderate increase in the blood sedimentation rate, laboratory findings are usually negative.

The Second or Degenerative Stage. There is usually a progression of the signs and symptoms of the incipient stage, especially the pain, limp, tenderness, muscle spasm, and limitation of motion Gill's sign is usually present, as well as the tenderness in the posterior hip region The febrile reaction may persist, and the blood sedimentation rate remains elevated The first positive bony roentgenographic findings occur in the metaphysis of the neck adjacent to the epiphyseal line. These bony changes are characterized by an irregular decalcification of the metaphysis and a widening of the epiphyseal plate There is also roentgenographic evidence of involvement of the capital epiphysis, characterized by the presence of a dense area in the head, usually in its central portion. This dense area gradually becomes irregularly decalcified but it may enlarge at the same time (Howorth). The head becomes fragmented and numerous dense areas are seen in varying stages of decalcification. During this stage the head may become wider, flatter, and thinner, and the neck may become thicker and shorter. As the joint swelling subsides, the head of the femur returns to its normal position in the socket and the lateral subluxation disappears (Gill)

Third or Regenerative Stage. The symptoms and signs will vary according to the severity of the disease and the extent of the pathologic changes. Ordinarily the signs and symptoms become less marked or entirely absent and the hip may appear practically normal The roentgenographic findings reveal a gradual recalcification of the decalcified areas in the capital epiphysis and metaphysis, and eventually normal trabeculations appear in the head If healing has not been complete, the head will retain its "mushroom" or "cap" deformity and manifest an incongruity with the shape of the socket.

The Residual Stage The symptoms and findings will depend on the completeness of the healing process The residual deformity is permanent, and traumatic arthritis may develop in later years because of the altered hip mechanics. There may be a permanent limp and limitation of motion of the hip with pain on fatigue or overuse, and some instability of the hip owing to the incongruity of the joint

Differential Diagnosis

Any child between the ages of three and 11 who complains of pain in the groin, anterior or medial aspect of the thigh, or medial aspect of the knee, who has a limp and some limitation of motion of the hip, especially in abduction and internal rotation, should be suspected of having coxa plana and kept off his feet until a definite diagnosis is made. The disease must be differentiated from synovitis of the hip, tuberculosis, slipping of the upper femoral epiphysis, rheumatic fever, rheumatoid arthritis, suppurative arthritis, osteomyelitis, and epiphysitis.

weight-bearing has been repeatedly emphasized by the studies of Brailsford. He states that "for upwards of four years until the last dense island has been replaced by normally ossified bone, the bone of the affected joint is plastic and could be deformed by pressure."



Fig 20.—The Fort or Snyder hip sling used to prevent weight-bearing on the affected extremity.

There are two operations which have been suggested to shorten the course of the degenerative stage and enhance healing of the disease process; the multiple drilling operation, and the Steele procedure. In the drilling operation (Bozsan; Ferguson and Howorth) several holes are drilled through the epiphyseal plate into the head directly through the trochanter or through a window in the neck of the femur. The drilling is done for the purpose of penetrating the diseased area of the head and thus producing more rapid revascularization and recalcification. Compere, Garrison, and Fahey, in experiments on dogs, found that this operation of multiple drilling uniformly resulted in growth arrest with a short femoral neck, irregular head, coxa vara, and shortening of the shaft, and concluded that "the operation of drilling of the neck of the femur in young children for the purpose of hastening revascularization of the head in cases of Legg-Calvé-Perthes disease is a very questionable procedure."

The Steele procedure attempts to accomplish the same purpose by removing



Fig 19.—Coxa plana in a boy six years old who had symptoms referable to the hip and knee for nine months prior to admission (A) Degenerative stage showing the massive subchondral degeneration of the head of the femur and changes in the metaphysis (B and C) Three years later, showing practically complete healing with mild residual flattening of the head and shortening and widening of the neck

with a poor roentgenologic result, but the latter is likely to develop symptoms at a later date, when pain and limitation of motion herald the onset of a traumatic arthritis. If the symptoms are mild, physiotherapy, procaine injections into the hip cuff muscles and hip joint, and short periods of immobilization with or without traction may be sufficient to carry the patient along for many years. At some time, however, there may be sufficient disability to make the decision for a more radical operative approach inevitable. These operative procedures include arthrodesis, arthroplasty, osteotomy, and various reconstructive operations, all designed to relieve pain, and, or, increase the function of the joint.

THE DO'S AND DON'TS IN THE MANAGEMENT OF COXA PLANA

(1) hildren between the ages of three and bed traction (so that they cannot bear

(2) as final, because the pathology in coxa es in the early stages of the disease.

(3) Don't make a negative diagnosis until all symptoms and signs have completely subsided and *repeated check roentgenograms are entirely negative.*

(4) Don't fail to get AP and lateral roentgenograms of both hips besides an AP view of the pelvis with both femurs in maximum *internal rotation*. A prominent lesser trochanter (external rotation position of the femur) may be the first clue to the diagnosis.

(5) Don't fail to scrutinize the shadow of the soft parts as well as the relative position of the heads in the acetabula in the roentgenogram A bulbous soft tissue swelling and a slight lateral luxation of the head out of the acetabulum are the first roentgenologic findings.

(6) Don't fail to examine carefully the width of the epiphyseal plate and the details of the metaphysis of the neck adjacent to the epiphyseal line Here are the first visible bony changes

(7) Don't neglect to obtain serial or repeated roentgenograms, not only for diagnostic purposes, but also to ascertain the stage and extent of the disease, and the healing process; and remember that both hips may become involved

(8) Don't forget that a slight limp, slight limitation of motion, especially in abduction and internal rotation, with or without pain or local hip tenderness, is the earliest clinical manifestation of the disease

(9) Don't forget to palpate the hip for a positive Gill sign A palpable enlargement of the hip is present in most hip conditions in children, especially when it is associated with a synovitis.

(10) Don't attempt to prognosticate the final outcome of the disease. It is a matter of close follow-up for three to five or more years.

(11) Don't take complete credit for treatment in good results. Remember that even in untreated cases it is possible to get an excellent hip. This point is important to remember for statistical reasons.

(12) Don't neglect to begin treatment early and continue it until the head has completely regenerated

(13) If you decide to treat the case by absolute restriction of weight-bearing, be certain that it is carried out In most cases, the restriction of weight-bearing is carried out intermittently even under hospital supervision, unless the patient is placed in traction or a cast

(14) Don't put too much faith in the hip sling Too often it is impossible to get the co-operation either of the patient or the parents.

(15) Don't resort to surgery unless the indication is present and your conviction as to its advisability and effectiveness substantiated There are as yet no accurate and convincing statistics that either drilling, bone grafting, or other operation is an acceptable method

(16) The primary treatment at present is *complete and absolute avoidance of weight-bearing. In order to achieve this it* will be necessary to obtain the wholehearted co-operation of the parents and patient because of the long period of treatment required

(17) Don't neglect physiotherapy and muscle conditioning exercises throughout the entire course of treatment

the necrotic bone from the epiphysis and then inserting small cancellous bone grafts into the space thus created. Neither of these operations has been widely accepted, and it will be some time before they can be properly evaluated.

Active physiotherapy and muscle training are important throughout this entire stage to ensure maximal functional restoration. When non-weight-bearing ambulation is prescribed, it is necessary also to employ measures to prevent adduction and other contractures. A night spreader splint can be used to advantage during this period.

The Third or Regenerative Stage. (Fig. 21). Weight-bearing should be avoided until it can be reasonably ascertained that the head will not become deformed as

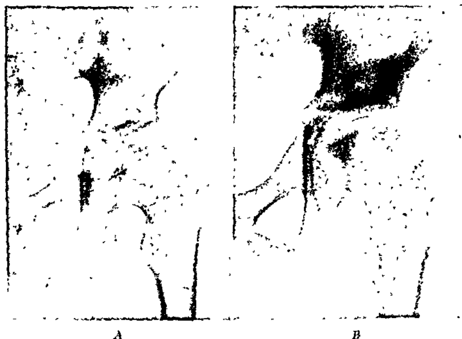


Fig. 21.—Coxa Plana. (A) Early regenerative stage one year after onset in five year old child. (B) Four years later, showing complete healing with a smooth well rounded head and widened neck.

a consequence thereof. Ordinarily speaking, therefore, some protection is needed for a considerable time during this period of regeneration and healing. It is during this time that the hip sling with crutches or the elevation of the opposite shoe and crutches can be used with a certain feeling of safety even though it may be recognized that the child will occasionally "cheat" and bear weight on the affected extremity. Physiotherapy, and muscle and joint rehabilitation are also important because healing is enhanced by activity of the part. The final decision as to when weight-bearing should be permitted must depend on the clinical as well as the roentgenographic findings, the latter usually being the more important. Gradually increasing weight-bearing should be accompanied by frequent clinical as well as roentgenologic examinations to determine the progress of the healing process and the presence of complications.

The Residual Stage. The treatment will depend on the degree of deformity and the extent of joint changes. A good clinical and functional result is often consistent

It seems apparent, therefore, that trauma is not the primary etiologic agent, except in the exceptional case in which the violence of the trauma could be considered sufficient to disrupt a normal epiphyseal line. In all others, the slipping is actually a pathologic process, similar to a pathologic fracture or dislocation.

Infection. Infection is sometimes regarded as the primary cause of the disease because of the mild fever and leukocytosis, the presence of a synovitis, and the increased sedimentation rate. As a result of the synovitis, there is involvement of the tissues about the neck of the femur and a consequent derangement of the metaphysis. However, cultures and tissue sections of the synovia have never shown the presence of bacteria. Occasionally there is a rather marked febrile reaction and the clinical course resembles that of an infectious arthritis.

Vascular Occlusion. The proponents of the vascular occlusion theory point to the characteristic metaphyseal changes seen in both slipping of the upper femoral epiphysis and coxa plana. Vascular occlusion may be either primary or secondary to the inflammation of the soft tissues. If early metaphyseal changes are common to both conditions, why does the head become involved in one and not in the other? One explanation is that the development of the head is more mature in later childhood than the development of the neck and the circulation of the head is improved by the development of collaterals from the ligamentum teres.

Endocrine Factor Many of the patients manifest a definite endocrine disturbance. They sometimes exhibit an atypical or a typical Frohlich's syndrome. Others are greatly overweight and have the ravenous appetite of a diabetic. Still others are tall and thin, but many are perfectly normal from a glandular standpoint.

A combination of any of the above etiologic agents may be the deciding factor in any given disease

Types of the Disease

There are two main types, the *acute or sudden* slipping, and the *chronic or gradual* slipping. Acute slipping may be a true traumatic entity when the force is sufficient to disrupt a normal epiphyseal line, or it may occur as a result of minimal trauma to a pathologic epiphyseal line. The former is rare and perhaps should not be included in a discussion of this disease. In the great majority of cases, the disease is characterized by a gradual or chronic slipping process.

Stages of the Disease

It is generally acknowledged that there are three principal stages in the disease, namely, the *preslipping stage,* the *slipping stage,* and the *residual stage.* The duration of the preslipping and slipping stages is dependent on the age at the onset of the disease, because the active process terminates when the epiphyseal line closes A careful history may disclose symptoms of preslipping for many months to a year or more before actual slipping occurred.

Pathology

The literature is singularly wanting in descriptions of the pathology of the hip in the early or preslipping stage. In a study of 17 operated hips in the preslipping stage, Howorth has given us an account of the pathologic changes in the soft tissues He found the capsule edematous and thickened, the synovial membrane

SLIPPING OF THE UPPER FEMORAL EPIPHYSIS

(*Epiphyseal or Adolescent Coxa Vara; Epiphyseal Coxa Anteverta; Epiphysiolysis; Epiphysiolysthesis*)

This affection is essentially a disease of the epiphyseal line of the neck of the femur which produces a pathologic separation between the head and neck with a consequent typical deformity Epiphysiolysis implies a "loosening or dissolving" of the line and is therefore descriptive of the early or preslipping stage. Coxa vara and coxa anteverta, on the other hand, define the characteristic deformity caused by the slipping The condition was first described by Sprengel in 1898.

Incidence

It is an interesting fact that whereas coxa plana occurs almost exclusively in boys during the middle childhood stage of the development of the hip between the ages of three and 10, this disease condition occurs in the late childhood or preadolescent stage between the ages of eight and 16, and that the incidence in girls gradually approaches that in boys The incidence of bilateral involvement also increases to about 20 per cent.

Theories Concerning the Etiology

Although the cause of slipping of the upper femoral epiphysis is unknown, the concept of its being a type of *dysplasia of the hip* appears logical. The plausibility of the dysplasia or growth disturbance concept is strengthened by the following facts. (1) It occurs during the period of accelerated growth of late childhood or early adolescence. (2) The earlier onset in girls, eight to 14 years, corresponds to their earlier maturity and cessation of growth. (3) Its first bony manifestations are in the metaphyseal side of the epiphyseal line, *the area of greatest growth differentiation of the hip* at this period. (4) A large percentage of the patients (65 *per cent) are either tall or overweight, suggesting a too rapid* growth acceleration or a basic metabolic process indirectly or directly affecting the growth and developmental process. (5) The disease is characteristically insidious and sometimes even asymptomatic. (6) It does not occur after the epiphyseal line *has closed and growth ceases (7) It has many of the same characteristics of coxa* plana, e.g., each occurs at a definite period in the growth and developmental process; each has certain special clinical and pathologic features in common, both are preceded by involvement of the soft parts, mainly a synovitis, and both show unmistakable evidence of vascular disturbance. Whereas coxa plana might be considered to be dysplasia of the hip involving chiefly the *capital epiphysis,* this disease could be considered as a dysplasia affecting mainly the *epiphyseal plate of the neck* The credibility of this concept is further supported by the occurrence of atypical cases of both diseases in the transitional period of growth.

Trauma. As in the case of coxa plana, it is difficult to evaluate the role of trauma in the causation of the disease A history of trauma of any significant degree is only occasionally given. When we consider the number and intensity of the traumatic forces to which the normal hip is constantly being subjected during this period of growth without affecting the epiphyseal line, it is difficult to believe that the mere "stepping off a curb" or some similar minor trauma could be the cause.

antedated the slipping by several months to more than a year. The initial complaint might only have been an experience of fatigue after strenuous exercise, or some vague discomfort referable to the hip Later, there may be a slight limp noticed only on unusual or strenuous activity. The pain in the hip may be referred to the medial aspect of the thigh or to the knee. Less frequently, the patient will complain of some limitation of motion or weakness of the hip.

The physical findings are comparable to those in the first stage of coxa plana. There may be a palpable swelling or fullness of the anterior aspect of the hip (Gill's sign) and local tenderness to deep palpation of the posterior aspect of the hip. There is usually some limitation of motion of the hip, especially in internal rotation, abduction, and flexion Clinical evidence of spasm of the hip cuff muscles, especially the external rotators, may also be present.

Laboratory examination is usually negative except for a slight increase in the white cell count and a moderate increase in the blood sedimentation rate.

Roentgenographic examination reveals a characteristic irregular loss of density of the metaphysis adjacent to the epiphyseal line, and a widening of the epiphyseal line. This area of rarefaction may increase to some extent before actual slipping occurs. The typical soft tissue swelling of the hip joint may also be discernible roentgenologically. The lateral films in this stage do not reveal any actual slipping.

Diagnosis in the Slipping Stage

The facility of diagnosis varies according to the degree and rapidity of the slipping. If slipping is slight and gradual, the symptoms and physical findings are not unlike those in the preslipping stage Ordinarily, however, there is a slight increase in the pain, limp, and limitation of motion Muscle spasm also increases, and the leg is held in a position of external rotation due to the spasm of the external rotators and also to the rotary displacement of the neck at the epiphyseal plate. The *roentgenographic findings are conclusive*. In the *anteroposterior view*, there is an increase in the width of the epiphyseal line comparable to the amount of slipping. Distortion between the head and neck may be so mild in the cases of slight slipping that it is discernible only when compared with the opposite side. In the lateral view, the exact amount of slipping can be accurately measured. As the slipping progresses, variable degrees of deformity between the head and neck are seen. The head is displaced downward and backward and the neck is displaced upward and forward, producing the typical varus and anteversion. The head of the femur may show evidence of aseptic necrosis, especially when slipping is pronounced, but it is an uncommon finding. The relative increased density of a portion of the head seen in the roentgenogram may in fact be due to the superimposed neck and not to actual necrosis.

Because the disease is often bilateral, and slipping of the opposite epiphysis may actually occur during the course of treatment, special consideration should be given to any complaints referable to the opposite hip and both hips should always be carefully scrutinized in the roentgenograms

Diagnosis in the Residual Stage

The residual or late stage represents the end results of the first two stages and the symptoms and findings are ordinarily dependent on the extent of the bony

and periosteum of the neck inflamed, and the synovial fluid increased. There was pannus formation at the synovial membrane and neck junction. Microscopically, there was evidence of perivascular round cell infiltration in the inflamed tissues. The soft tissue involvement was also prominent after slipping had occurred, and sclerotic changes gradually became superimposed. The epiphyseal plate remained soft for a while, then became hard and solidly ossified. As a result of the slipping, various degrees of posterior displacement of the head on the neck occurred. In the acute slipping, the head is usually entirely separated from the neck, but in the chronic or gradual slipping there is always a firm layer of fibrous or cartilaginous tissue covering the exposed portion of the neck and joining it to the cartilage of the head so that there is no actual separation of the head from the neck. The pathologic picture in the residual stage varies according to the degree of slipping, the secondary changes occurring in the head and neck, the secondary adaptive changes in the socket, and the pathology of the soft parts. Varying degrees of aseptic necrosis of the head are observed in about 10 per cent of the cases, and sometimes the entire head may appear to be involved; but even then the character of the necrosis is not the same as seen in coxa plana (Gill, Brailsford). The neck usually shows some residual varus deformity (epiphyseal or adolescent coxa vara) and may be markedly anteverted (epiphyseal coxa anteverta).

Prognosis

The prognosis is always doubtful because of the difficulty of predicting the ultimate changes in the head and neck regardless of the treatment instituted. Blount expresses the futility of accurate prognostication in this manner: "In some with little or no treatment results are often brilliant, whereas in others even with the most energetic treatment the results are catastrophic." An excellent functional result is often compatible with an unsatisfactory roentgenogram, and an apparently perfect roentgenologic result is sometimes associated with a stiff and painful hip. This is probably due to the difficulty in evaluating the extent of the residual damage to the soft tissues, especially the synovial membrane and the capsule. However, as a general rule, the earlier the diagnosis is made and treatment instituted, the better the prognosis, and the later the onset with respect to the termination of growth and closure of the epiphyseal line, the better the prognosis. If the onset is during the transitional period of growth between middle and late childhood (nine to 11 years), the prognosis should be especially guarded because of the greater tendency for the head to become involved and the prolonged period of treatment and/or observation required.

Diagnosis in the Preslipping Stage

Because of the insidiousness of the onset, the diagnosis is infrequently made in the preslipping stage. The first symptoms are generally so mild and non-incapacitating that the parents cannot be blamed for not calling in a physician, and the physical findings may be so equivocal that the general practitioner, who usually sees the patient first, is apt to miss the diagnosis. As a result few of these cases are seen by the orthopedic surgeon until actual slipping has occurred, and often not until slipping has progressed to some extent.

A careful history will usually disclose that the first symptoms of the disease

antedated the slipping by several months to more than a year. The initial complaint might only have been an experience of fatigue after strenuous exercise, or some vague discomfort referable to the hip Later, there may be a *slight limp* noticed only on unusual or strenuous activity The pain in the hip may be referred to the medial aspect of the thigh or to the knee Less frequently, the patient will complain of some limitation of motion or weakness of the hip.

The physical findings are comparable to those in the first stage of coxa plana. There may be a palpable swelling or fullness of the anterior aspect of the hip (Gill's sign) and local tenderness to deep palpation of the posterior aspect of the hip. There is usually some limitation of motion of the hip, especially in internal *rotation, abduction, and flexion Clinical evidence of spasm of the hip cuff muscles,* especially the external rotators, may also be present.

Laboratory examination is usually negative except for a slight increase in the white cell count and a moderate increase in the blood sedimentation rate.

Roentgenographic examination reveals a characteristic irregular loss of density of the metaphysis adjacent to the epiphyseal line, and a widening of the epiphyseal line. This area of rarefaction may increase to some extent before actual slipping occurs. The typical soft tissue swelling of the hip joint may also be discernible roentgenologically. The lateral films in this stage do not reveal any actual slipping.

Diagnosis in the Slipping Stage

The facility of diagnosis varies according to the degree and rapidity of the slipping. If slipping is slight and gradual, the symptoms and physical findings are not unlike those in the preslipping stage Ordinarily, however, there is a slight increase in the pain, limp, and limitation of motion Muscle spasm also increases, and the leg is held in a position of external rotation due to the spasm of the external rotators and also to the rotary displacement of the neck at the epiphyseal plate. The roentgenographic findings are conclusive In the anteroposterior view, there is an increase in the width of the epiphyseal line comparable to the amount of slipping. Distortion between the head and neck may be so mild in the cases of *slight slipping* that it is discernible only when compared with the opposite side. In the lateral view, the exact amount of slipping can be accurately measured. As the slipping progresses, variable degrees of deformity between the head and neck are seen. The head is displaced downward and backward and the neck is displaced upward and forward, producing the typical varus and anteversion. The head of the femur may show evidence of aseptic necrosis, especially when slipping is pronounced, but it is an uncommon finding The relative increased density of a portion of the head seen in the roentgenogram may in fact be due to the superimposed neck and not to actual necrosis.

Because the disease is often bilateral, and slipping of the opposite epiphysis may actually occur during the course of treatment, special consideration should be given to any complaints referable to the opposite hip and both hips should always be carefully scrutinized in the roentgenograms

Diagnosis in the Residual Stage

The residual or late stage represents the end results of the first two stages and the symptoms and findings are ordinarily dependent on the extent of the bony

deformity and the healing of the soft parts. If only minimal slipping is present and the healing of the epiphyseal line and soft tissues uncomplicated, the hip may return to normal with little or no loss of function. If, on the other hand, the course is complicated by aseptic necrosis of the head, varus and anteversion of the neck, or extensive scarring of the soft tissues, the result may be a stiff hip, shortening, limp, and deformity.

Differential Diagnosis

Any boy between the ages of 10 and 16, and any girl between the ages of eight ... able to the hip, especially pain ... of the upper femoral epiphysis ... This condition must be differentiated from coxa plana, synovitis of the hip, subacute infectious processes, early tuberculosis, osteomyelitis, epiphysitis, congenital coxa vara, and fractures of the neck of the femur.

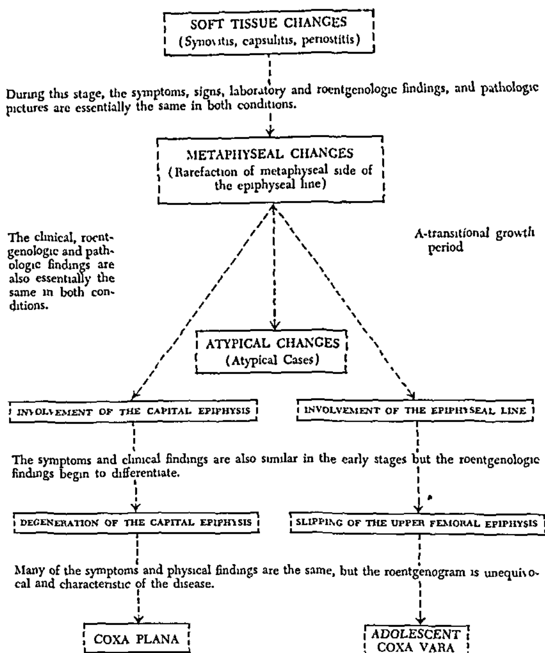
The analogy and differential diagnosis between slipping of the upper femoral epiphysis and coxa plana are illustrated in the following chart:

Treatment

The treatment of this disease is one of the most controversial subjects in current orthopedic practice Reports in the literature are extremely variable and usually are based on a relatively small number of cases. The very fact that excellent results can be achieved by seemingly paradoxical approaches would lead one to believe that there must be a marked variability in the severity and course of the disease Some cases probably do not progress beyond the preslipping stage, especially if the time of onset was at or near the cessation of growth and closure of the epiphyseal line Once slipping has started, progression cannot be considered as inevitable, because healing may take place at any time, especially if the onset of the slipping approximated the time of the normal closure of the epiphyseal line. Many of these cases undoubtedly heal spontaneously without ever having been recognized and with little or no deformity In the treatment of this condition, therefore, we should be guided by certain factors which are applicable to the individual case First of all, the disease is limited to the late period of growth of the upper end of the femur and cannot occur after the epiphyseal line has closed. Therefore, if the disease manifested itself at about the age of 14 or 15 years, the course would be relatively short and corresponding therapeutic measures indicated If, however, the disease occurred at the age of 10 or 11, the plan of treatment would have to take into consideration the fact that the disease process cannot be said with certainty to be terminated until the epiphyseal line has closed That would mean about four years of treatment and/or observation

Treatment in the Preslipping Stage. The fundamental principle of treatment is the recognition of the disease before slipping has occurred, and the prevention of actual slipping The latter can be accomplished by conservative measures or by operation.

Conservative Measures Designed to Prevent Actual Slipping of the Epiphysis. The following methods have been recommended: (1) recumbency with or without traction, (2) crutches and elevated shoe on the unaffected side; (3) long leg



ischial bearing brace; (4) the internal rotation brace designed by Milch; (5) the Whitman plaster spica with or without an incorporated walking iron; (6) the hip sling of Fort and Snyder.

Complete bed rest with traction and the thigh in a position of slight flexion and moderate abduction and internal rotation is an effective preliminary step in treatment. It has the advantage of relieving the muscle spasm as well as permitting joint motion while the leg is held in a position in which slipping is not likely to

deformity and the healing of the soft parts. If only minimal slipping is present and the healing of the epiphyseal line and soft tissues uncomplicated, the hip may return to normal with little or no loss of function. If, on the other hand, the course is complicated by aseptic necrosis of the head, varus and anteversion of the neck, or extensive scarring of the soft tissues, the result may be a stiff hip, shortening, limp, and deformity.

Differential Diagnosis

Any boy between the ages of 10 and 16, and any girl between the ages of eight and 14, who complains of vague symptoms referable to the hip, especially pain and limp, should be suspected of having slipping of the upper femoral epiphysis and be put to bed until a diagnosis is established This condition must be differentiated from coxa plana, synovitis of the hip, subacute infectious processes, early tuberculosis, osteomyelitis, epiphysitis, congenital coxa vara, and fractures of the neck of the femur

The analogy and differential diagnosis between slipping of the upper femoral epiphysis and coxa plana are illustrated in the following chart.

Treatment

The treatment of this disease is one of the most controversial subjects in current orthopedic practice. Reports in the literature are extremely variable and usually are based on a relatively small number of cases. The very fact that excellent results can be achieved by seemingly paradoxical approaches would lead one to believe that there must be a marked variability in the severity and course of the disease. Some cases probably do not progress beyond the preslipping stage, especially if the time of onset was at or near the cessation of growth and closure of the epiphyseal line. Once slipping has started, progression cannot be considered as inevitable, because healing may take place at any time, especially if the onset of the slipping approximated the time of the normal closure of the epiphyseal line. Many of these cases undoubtedly heal spontaneously without ever having been recognized and with little or no deformity. In the treatment of this condition, therefore, we should be guided by certain factors which are applicable to the individual case. First of all, the disease is limited to the late period of growth of the upper end of the femur and cannot occur after the epiphyseal line has closed. Therefore, if the disease manifested itself at about the age of 14 or 15 years, the course would be relatively short and corresponding therapeutic measures indicated. If, however, the disease occurred at the age of 10 or 11, the plan of treatment would have to take into consideration the fact that the disease process cannot be said with certainty to be terminated until the epiphyseal line has closed. That would mean about four years of treatment and/or observation.

Treatment in the Preslipping Stage. The fundamental principle of treatment is the recognition of the disease before slipping has occurred, and the prevention of actual slipping. The latter can be accomplished by conservative measures or by operation

Conservative Measures Designed to Prevent Actual Slipping of the Epiphysis The following methods have been recommended: (1) recumbency with or without traction; (2) crutches and elevated shoe on the unaffected side; (3) long leg

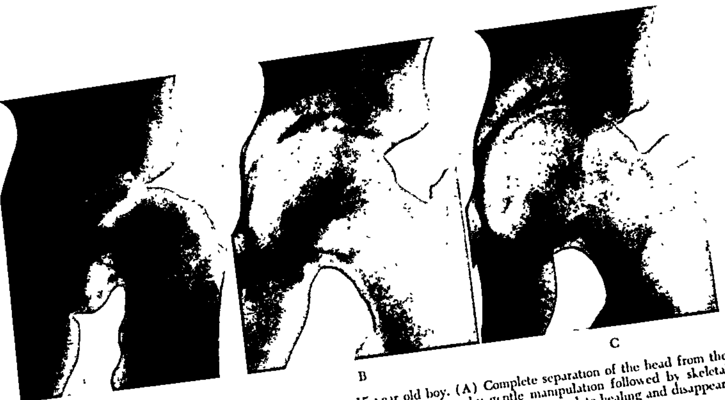


Fig. 22.—Acute slipping of the upper femoral epiphysis in a 15 year old boy. (A) Complete separation of the head from the neck with marked coxa vara. (B) Four and one half months after reduction by gentle manipulation followed by skeletal traction and immobilization in a plaster spica. (C) Nine months after reduction, showing a complete healing and disappearance of the epiphyseal line. Note the shortened neck.

occur. Bed rest with traction is recommended for at least the duration of the muscle spasm, but it may be continued indefinitely as in the treatment of coxa plana.

Crutches and elevation of the shoe on the unaffected side is a risky procedure because it is no guarantee against weight-bearing, and the pendulum weight of the leg tends to provoke the external rotation and torsion deformity between the head and the neck.

The internal rotation brace treatment recommended by Milch is an improvement over the ordinary ischial bearing long leg brace, because it tends to prevent external rotation of the leg and at the same time permits weight-bearing. Protective brace treatment, however, has not gained wide recognition as a safe method for preventing slipping of the epiphysis, but it may be used as an adjunct to other forms of treatment.

The Whitman plaster cast is probably the safest and best treatment in the preslipping stage for the general practitioner. If the details of the application of the plaster spica are meticulously adhered to, the Whitman cast will insure immobilization of the hip as in the case of fractures of the neck of the femur. The thigh should be in a comfortable position of maximal abduction and internal rotation, the knee slightly flexed, and the hip extended. The cast is usually applied after a preliminary period of traction to relieve muscle spasm or a slight hip flexion contracture from involvement of the capsule. It has the disadvantages that accompany prolonged immobilization without function, even though walking is permitted in the cast.

Surgical Measures Designed to Prevent Further Slipping. The surgical approach to the problem of slipping of the upper femoral epiphysis has in the past 10 years become so popular in certain sections of the country that it is being strongly recommended as the treatment of choice even in the preslipping stage. Surgery has two important advantages to offer, namely, *internal fixation* and *fusion* of the epiphyseal line (epiphysiodesis). Internal fixation may be used alone without opening the joint, or combined with operative procedures directed at the epiphyseal plate for the purpose of obtaining early fusion between the head and neck. Many types of internal fixation have been successfully used, the most common being. (1) the Smith-Petersen nail, (2) the multiple Moore nails or Knowles pins, (3) the Lippmann screw, (4) single or multiple Steinman pins, (5) multiple screws Although internal fixation is designed mainly to prevent actual slipping or further slipping, it sometimes also hastens ossification of the plate and healing of the process. Surgical approach to the epiphyseal plate by opening into the hip joint is seldom used in the preslipping stage. Howorth, however, recommends the procedure, and places several thin cancellous bone grafts across the epiphyseal line for the purpose of producing an early fusion (epiphysiodesis) between the head and neck. Internal fixation has also the distinct advantage of functional activity of the extremity during the entire healing process.

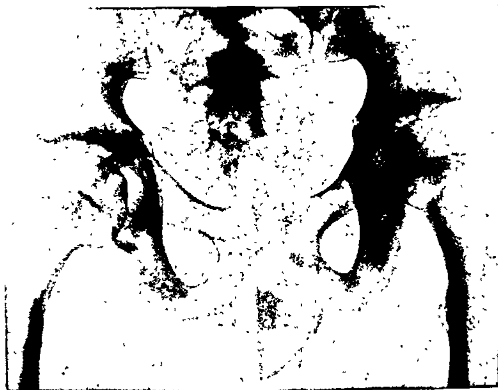
Treatment in the Slipping Stage. Slipping of the epiphysis is usually regarded as an emergency requiring immediate treatment. The nature of the treatment will depend on the type and extent of the slipping process.

Acute Slipping: The head is usually completely separated from the neck (Fig. 22). If the violence of the trauma was sufficient to displace a normal epiphysis,



Fig. 22.—Acute slipping of the upper femoral epiphysis in a 15 year old boy. (A) Complete separation of the head from the neck with marked coxa vara. (B) Four and one half months after reduction by gentle manipulation followed by skeletal traction and immobilization in a plaster spica. (C) Nine months after reduction, showing a complete healing and disappearance of the epiphyseal line. Note the shortened neck.

it may be a true traumatic slipping. Ordinarily, however, the separation is due to a pathologic slipping of the epiphysis. In either case, it is necessary to reduce the displacement. This can be accomplished either conservatively or by operation. As in the case of fractures of the neck of the femur, the displaced head may be replaced by manual reduction, as recommended by Ghormley, or by continuous traction, as recommended by Burns and Ellis, and Irwin (Fig. 24). After reduction, the hip is either immobilized in a Whitman plaster spica, or reduction may be maintained by continuous traction until the epiphyseal line has healed. Reduction may also be maintained by means of internal fixation with a Smith-Petersen



Right A Left

not discovered until a few weeks later.

nail or other methods already outlined. If closed reduction fails, it will be necessary to resort to open reduction, with or without internal fixation and/or fusion of the epiphyseal line In any case, some type of immobilization must be continued until healing has occurred, applying the same principle which governs the treatment of fractures of the neck of the femur. Complete healing of the slipped epiphysis cannot be present before the epiphyseal line has actually closed. It is, therefore, necessary to continue treatment until growth ceases to obtain the best results. Absolute immobilization need not be continued throughout this period, however, as the hip may be protected by braces and splints while at



B



C

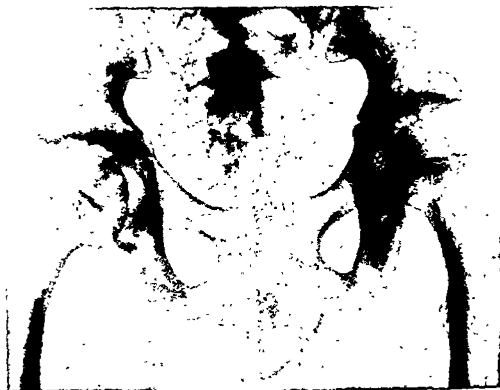


D

Fig 23B,C,D —Anteroposterior and lateral views of the right hip, showing a gradual increase in the slipping Anteroposterior view of the right hip following open reduction and internal fixation by means of a Smith-Petersen nail.

(Courtesy of Dr. I. M. Flinn, Jr.)

it may be a true traumatic slipping. Ordinarily, however, the separation is due to a pathologic slipping of the epiphysis. In either case, it is necessary to reduce the displacement. This can be accomplished either conservatively or by operation. As in the case of fractures of the neck of the femur, the displaced head may be replaced by manual reduction, as recommended by Ghormley, or by continuous traction, as recommended by Burns and Ellis, and Irwin (Fig. 24). After reduction, the hip is either immobilized in a Whitman plaster spica, or reduction may be maintained by continuous traction until the epiphyseal line has healed. Reduction may also be maintained by means of internal fixation with a Smith-Petersen



[illegible] not discovered until a few weeks later.

nail or other methods already outlined. If closed reduction fails, it will be necessary to resort to open reduction, with or without internal fixation and/or fusion of the epiphyseal line In any case, some type of immobilization must be continued until healing has occurred, applying the same principle which governs the treatment of fractures of the neck of the femur. Complete healing of the slipped epiphysis cannot be present before the epiphyseal line has actually closed. It is, therefore, necessary to continue treatment until growth ceases to obtain the best results. Absolute immobilization need not be continued throughout this period, however, as the hip may be protected by braces and splints while at

is therefore probably no longer possible. In view of the above, positive rules for treatment cannot be laid down.

Generally speaking, there are three main forms of conservative treatment: (1) gentle manual reduction by forced abduction and internal rotation and immobilization in a Whitman plaster spica or retention by means of continuous traction as in the preslipping stage; (2) reduction by strong skeletal traction with gradually increasing internal rotation and abduction and immobilization as above (Fig. 24); (3) a modification of the traction and plaster immobilization, the so-called "traction-spica-traction" method of Green. Reduction is gradually obtained by preliminary skin traction in two directions for a period of about three weeks. There are two traction forces applied, one longitudinal of about 10 pounds and the other an internal rotation traction of about 5 pounds applied by means of a wide moleskin adhesive about the middle of the thigh. After reduction, a plaster spica which includes the foot on the involved side and the thigh on the opposite side is applied. Immobilization is continued for about three months, followed by a second period of traction during which exercises of the hip and extremity are instituted. The following advantages have been advanced for the traction-spica-traction method: (a) there is no interference with the blood supply of the femoral head; (b) the muscle spasm is relieved by traction, thus allowing increasing internal rotation and abduction, (c) slipping cannot increase; (d) if the displacement is not too great, the surface smooths off as the process heals; (e) immobilization in plaster promotes healing and has not produced stiff hips with this method. Chandler definitely agrees with this conservative approach, and Blount considers it probably the best for the general practitioner. Skeletal traction may be used instead of skin traction. A Steinman pin or Kirschner wire is inserted through the supracondylar region of the femur and both longitudinal and internal rotation traction applied. It has the advantage of being a more positive method of traction as it is applied directly through the bone, and the fact that greater amounts of traction can be more easily applied.

Regardless of the conservative method employed, it may be necessary to protect the hip from weight-bearing and a recurrence of the slipping for a considerable length of time and to employ such physiotherapeutic measures as will restore the function of the hip joint For this purpose, an ischial-bearing long leg brace, the Milch internal rotation brace, or a hip sling may be used to advantage. Short periods of traction are also indicated to prevent contractures, stretch the scarred soft tissues, and increase the motion of the joint. A night spreader splint may also be advisable with or without mild traction to protect the hip during the night. Too early weight-bearing, neglect to protect the hip during convalescence, and failure to institute proper physical rehabilitation measures, will completely nullify an otherwise successful treatment.

Operative Treatment of Chronic or Gradual Slipping: As in the case of the surgical treatment of the preslipped epiphysis, surgery in the slipping stage is designed to prevent further slipping by internal fixation and to hasten fusion of the epiphyseal line. In addition, surgery in this stage is performed to reduce the displacement by an osteotomy either through the epiphyseal line (Wilson, Klein et al.), or distal to the epiphyseal line (Ghormley and Fairchild; Callahan). The surgical procedure indicated in any specific case is ordinarily determined by the

the same time permitting motion and guarded function when the healing has been judged to be sufficiently advanced.

Chronic or Gradual Slipping (Fig. 23, A,B,C,D,E,): The head is usually quite firmly adherent to the neck, and reduction is therefore considerably more difficult than in cases of acute slipping. The facility of reduction will depend on the plasticity of the slipping site and the degree of slipping. If the head is firmly adherent to the neck, manual reduction is impossible and fraught with danger of damage to the head and other structures of the hip joint. If slipping is minimal, manipulative reduction is usually unsuccessful and inadvisable. Howorth states that reduction should not be attempted unless the slipping has progressed more than 0.5



Fig 23E —Drawing of an old slipping of the upper femoral epiphysis as it appeared at operation. (After Shands)

inch, whereas in Ghormley's opinion manipulative reduction should never be attempted in cases of chronic slipping That good results have been obtained by manual reduction would indicate that neither the character or progress of the slipping nor the firmness of the adhesion of the head to the neck is the same in any group of cases. It is possible that the progress of the slipping is extremely slow and relatively benign in some cases, while in others there is a slight slip and then healing. The extreme difficulty of determining the time of onset and therefore also the stage of the process would explain the fact that in some cases the line remains relatively soft for many months while in others it becomes almost as hard as ivory within a surprisingly short time. In the latter event, further slipping

Klein et al. also osteotomize through the plate but fix the head by means of a Smith-Petersen nail. Blount, on the other hand, found results from the Smith-Petersen nail so bad that he was forced to use the smaller Moore nails. Ghormley and Fairchild of the Mayo Clinic perform a cuneiform osteotomy of the neck of the femur below the epiphyseal line, followed by immobilization in a Whitman spica. Callahan does the osteotomy just distal to the line also, but he recommends internal fixation with two long screws. The distal fragment is drilled with larger holes than the proximal in order that the head may be drawn tightly to the neck. Callahan further stresses the importance of producing a valgus between the head and neck in order to gain length, and concluded: "I am convinced that the only treatment for slipped capital femoral epiphysis is early traction followed by surgery and internal fixation." Klein, Joplin, and Reidy reported on the results of treatment at the Massachusetts General Hospital, and recommend (1) closed Smith-Petersen nailing if the slip is minimal; (2) open reduction and nailing (Smith-Petersen) if the slip is pronounced; (3) early postoperative mobilization by Buck's extension for blind nailing, and balanced traction for open nailing; (4) manipulation only in the recent acute cases; (5) for pronounced slip, osteotomy at the epiphyseal plate.

Those who dislike the Smith-Petersen nail point to its relatively large size and the possibility of producing traumatic and circulatory damage to the head of the femur, especially when the epiphyseal line is unusually hard. In the latter case, at least, it would appear that the use of multiple smaller nails or screws would be more desirable.

Almost everyone is in agreement that the viability of the head of the femur is a determining factor in treatment. If the case is seen late and the displacement of the head and neck is pronounced, it is probable that the vessels on the anterior and lateral aspects of the neck have been torn or otherwise damaged, and it is therefore necessary to determine the status of the remaining blood supply to the head before specific therapeutic measures are instituted. This may be done either by roentgenologic evaluation or at the time of open operation. Because the blood supply to the head in cases of marked slipping must come mainly from the posterior and inferior aspect of the neck (retinaculum of Weitbrecht), therapeutic measures to correct the displacement may interrupt this essential circulation and should be avoided (Green). It is fortunate that, except in the very young, aseptic necrosis of the femoral head is not a common complication of slipped upper femoral epiphysis, perhaps because of the development of collateral circulation in the preadolescent stage of development of the hip. Should this serious complication occur, much more radical surgical procedures will be required to restore at least partial function of the joint.

Treatment in the Late or Residual Stage

The treatment of the late or residual stage is directed at the deformity. Various operative procedures have been recommended, such as osteotomies, arthrodeses, and arthroplasties. The most widely used and recommended operation is the subtrochanteric or intertrochanteric osteotomy for the correction of the varus and anteversion deformities. After the osteotomy, the corrected position is usually maintained by a plaster spica. However, internal fixation by means of the Blount

extent of the slipping. If only minimal slipping has occurred, the hip joint is ordinarily not exposed, and so-called blind internal fixation with a Smith-Petersen nail (Fig. 23 D), screws, or smaller Knowles pins or Moore nails is usually the method of choice If, however, the slipping is more pronounced, internal fixation



Fig 24 —Reduction of a slipped upper femoral epiphysis by skeletal traction and gradually increasing internal rotation and abduction A Steinman pin has been inserted in the supracondylar region of the femur and an internal rotation force is applied to the outer end of the traction bow.

is combined with open reduction with or without bone grafting across the epiphyseal line Variations in the surgical technic are often demanded by the pathology encountered when the hip joint is exposed Much will depend on the viability of the head of the femur. Kleinberg and Buchanan recommend osteotomy through the epiphyseal plate and securing the head with an ivory peg. Wilson and

REFERENCES

Abbott, L. C : Treatment of Old Congenital Dislocation of Hip, with Special Reference to Use of Skeletal Traction before Reduction by Operation. *Arch. Surg*, *12*:983, 1926.

Adams, Z. B.: The Treatment of Congenital Dislocation of the Hip as Practiced by Professor Denuce at Bordeaux, France. *J. Bone & Joint Surg*, *4*:523, 1922.

Allam, M V.: Personal Communication.

Allison, N.: The Open Operations for Congenital Dislocation of the Hip; in *Robert Jones Birthday Volume.* London: Oxford University Press, 1928.

Allison, N.: A Study of the Anatomy of Congenital Dislocation of the Hip after Manipulative Reduction. *Am J. Orthop. Surg.*, *3*:157, 1905-1906.

Arey, L B.: *Developmental Anatomy: A Textbook and Laboratory Manual of Embryology* Philadelphia: W. B. Saunders Company, 1946.

Badgley, C. E. et al.: Operative Therapy for Slipped Upper Femoral Epiphysis. *J. Bone & Joint Surg.*, *30*:19, 1948.

Badgley, C E . Correlation of Clinical and Anatomical Facts Leading to Conception of Etiology of Congenital Hip Dysplasias, President's Address. *J. Bone & Joint Surg*, *25*:503, 1943.

Badgley, C. E. et al.: End-result Study of Operative Therapy for Slipped Upper Femoral Epiphysis. *Univ. Hosp. Bull., Ann Arbor, 13* 41, 1947.

Barr, J. S.: Congenital Coxa Vara. *Arch. Surg*, *18*.1909, 1929

Bergmann, E.. Theoretisches, klinisches und experimentelles Studien zur Frage der aseptischen Knochennekrosen. *Deutsche Ztschr. f. Chir*, *206*:12, 1927.

Blount, W. P.: Peg Leg Cast. *J. Bone & Joint Surg*, *13*:107, 1931.

Bohm, M.: Embryologic Origin of Club-foot. *J. Bone & Joint Surg*, *11*:229, 1929.

Bomfin, DaC. R.. Prelussazione e piedi torti. *Chir. d. org. di movimento, 23.181, 1937.*

Bozsan, E. J.. New Treatment of Intracapsular Fractures of Neck of Femur and Calvé-Legg-Perthes Disease *J. Bone & Joint Surg*, *14*.884, 1932.

Brailsford, J. F.. *Avascular Necrosis of Bone J. Bone & Joint Surg.*, *25*.249, 1943.

Brewster, A. H . Congenital Dislocation of Hip in *Surgical Treatment of the Motor-Skeletal System.* Philadelphia: J. B. Lippincott Company, 1945.

Bruce, J · A Reconsideration of Congenital Dislocation of the Hip in Childhood *Practitioner, 125*.642, 1930.

Buchman, J : Résumé of Osteochondritides. *Surg, Gynec. & Obst*, *49*.447, 1929.

Burns, B. H , and Ellis, V. H. *Recent Advances in Orthopaedic Surgery.* London: J. & A. Churchill, 1937.

Callahan, J. J.: Treatment of Slipping of the Upper Femoral Epiphysis. Personal Communication.

Calvé, J : Osteochondritis of the Upper Extremity of the Femur. *J. Orthop. Surg*, *3* 489, 1921.

Carey, E. J Direct Observations on the Transformation of the Mesenchyme in the Thigh of the Pig Embryo (Sus scrofa), with Special Reference to the Genesis of the Thigh Muscles, of the Knee-Hip Joints, and of the Primary Bone of the Femur. *J. Morphol.*, *37*:1, 1922-23.

Cavanaugh, L. A , Shelton, E K., and Sutherland, R . Metabolic Studies in Osteochondritis of Capital Femoral Epiphysis. *J Bone & Joint Surg*, *18*.957, 1936

Chandler, S B., and Kreuscher, P. H.: Study of Blood Supply of Ligamentum Teres and Its Relation to Circulation of Head of Femur. *J. Bone & Joint Surg*, *14*·834, 1932.

Chandler, F. A.: Congenital Dislocation of Hip, Anatomical Study of Case of Bilateral Congenital Dislocation of Hip and Other Associated Congenital Deformities in Male Infant 11 Days Old. *J. Bone & Joint Surg*, *11*.546, 1929.

Chapple, C. Changes in Bone Secondary to Local and Generalized Disturbances, in Mitchell-Nelson *Textbook of Pediatrics* Philadelphia W B Saunders Company, 1945.

Coghill, G. E.. Early Development of Behavior in Amblystoma and in Man. *Arch. Neurol & Psychiat*, *21*:989, 1929

Colonna, P. C . Arthroplastic Procedure for Congenital Dislocation in Children. *J. Bone & Joint Surg*, *20*.604, 1938

or Jewett blade-plate, Smith-Petersen nail with Thornton plate, and others, are frequently used and often desirable. If considerable pain and limitation of motion *are present, it may be necessary to perform an arthrodesis or arthroplasty. In the* latter case, the Smith-Petersen vitallium cup arthroplasty is most commonly used. J. R Moore has devised a "cartilage cup" type of arthroplasty in which the cartilage of the head is first carefully removed, the deformity corrected, and the cartilage cap replaced over the reshaped neck. Many other operations have been successfully used and recommended, depending on the residual pathology, and, as in the case of coxa plana, they all have the same objectives, namely, the relief of symptoms and the correction of the deformity (Colonna; Whitman et al.).

THE DO'S AND DON'TS IN THE MANAGEMENT OF SLIPPED UPPER FEMORAL EPIPHYSIS

(1) Don't fail to make an early diagnosis. Remember that any adolescent with mild symptoms referable to the hip, with or without history of mild trauma, should be treated for early epiphysiolysis (slipped epiphysis) unless proved otherwise

(2) *Do put the patient to bed and prohibit weight-bearing* while you are making the diagnosis

(3) Don't let a negative roentgenologic report influence you in your diagnosis Get AP and lateral views of both hips and AP views of the pelvis with the femurs in full internal rotation, and view these films yourself in the light of the physical findings

(4) Don't forget that the earliest clinical sign is slight limitation of *INTERNAL rotation*, and *abduction*, and that the earliest roentgenographic findings are a slight widening of the *epiphyseal* plate and *rarefaction on the diaphyseal side of the epiphyseal line.*

(5) Don't fail to get AP and lateral roentgenograms of both hips both before and during treatment, because both may be involved, or may eventually become so.

(6) Don't permit the minimal roentgenographic and clinical findings to give a false sense of security either in your plans for treatment or your prognosis.

(7) Don't forget that the earlier the treatment the better the prognosis, but that in spite of everything the result may be poor.

(8) Do plan your treatment according to the pathology present, the stage of the slipping, and the individual patient concerned.

(9) Don't use force under any circumstances in your manipulations—you may permanently damage the circulation of the head.

(10) Don't try to reduce slippings of less than 0 5 inch by manipulation because they are usually unsuccessful and may do harm

(11) In the average hands, the conservative method of treatment should always be that of choice, even in the slipping stage

(12) In the hands of the skilled orthopedic surgeon the operative treatment may be the method of choice even in the preslipping stage.

(13) Don't use the contradictory reports in the literature as an excuse for bad results. It is your responsibility to follow accredited methods carefully and meticulously to the last detail according to your own individual ability.

(14) Don't forget that poor results are often the *avoidable consequences of treatment* and *not the unavoidable consequences of the disease.*

(15) Don't make the grave mistake of allowing too early weight-bearing, especially without protection.

(16) Don't neglect to protect the hip throughout the entire period of convalescence and until the epiphyseal line has closed

(17) Don't fail to institute proper physical rehabilitation measures

(18) Don't discharge the patient from your care until the epiphyseal line has closed and until everything has been done to give the patient a normal hip, or as nearly normal as possible *You may therefore have to follow the patient for five years, or longer.*

Galeazzi, R.: Ueber die unblutige Behandlung der kongenitalen Hueftgelenkverrenkung. *Ztschr. f. Orthop*, *31*:202, 1913.

Galloway, H. P.: Open Operation for Congenital Dislocation of Hip; Special Reference to Results. *J. Bone & Joint Surg*, *8*:539, 1926.

Gill, A. B.: The Operative Treatment of Congenital Dislocation of the Hip; Indications and Method. *Reg. Orthop. Surg & Fund Orthop. Prob*, *No. 11*, 1947.

Gill, A. B : Relationship of Legg-Perthes Disease to Function of Thyroid Gland. *J. Bone & Joint Surg.*, 25 892, 1943.

Gill, A. B.: End Results of Bloodless Reduction of Congenital Dislocation of Hip. *J. Bone & Joint Surg*, 25:1, 1943

Gill, A B.: Legg-Perthes Disease of Hip, Its Early Roentgenographic Manifestations and Its Cyclical Course *J. Bone & Joint Surg*, 22:1013, 1940.

Gill, A B : Evaluation of Present-day Methods of Dealing with Congenital Dislocation of Hip. *J. Bone & Joint Surg*, *18*:487, 1936

Gill, A. B : Plastic Construction of Acetabulum in Congenital Dislocation of Hip Shelf Operation. *J. Bone & Joint Surg*, *17*:48, 1935.

Gill, A. B . Operation for Old or Irreducible Congenital Dislocation of Hip. *J. Bone & Joint Surg*, 10 696, 1928.

Ghormley, R K., and Fairchild, R. D.: Diagnosis and Treatment of Slipped Epiphysis. *J.A M.A*, *114* 229, 1940.

Green, W. T.: Slipping of Upper Femoral Epiphysis; Diagnostic and Therapeutic Considerations. *Arch. Surg*, *50*:19, 1945.

Groves, E. W. H.: The Treatment of Congenital Dislocation of the Hip Joint, with Special Reference to Open Operative Reduction, in *Robert Jones Birthday Volume.* London: Oxford University Press, 1928.

Hark, F W.: Treatment of Separation of Upper Femoral Epiphysis. *S. Clin. North America*, 22 119, 1942.

Hart, V. L Primary Genetic Dysplasia of Hip with and without Classical Dislocation. *J. Bone & Joint Surg*, *24*:753, 1942

Hass, J.: Congenital Dislocation of the Hip; Fifty Year Survey. *J. Internat. Coll Surgeons*, 9·152, 1946

Hibbs, R. A . Anteversion of the Neck of the Femur, in Connection with Congenital Dislocation of the Hip. *J A M A*, *65*.1801, 1915

Hoffa, A : Zur operativen Behandlung der angeborenen Hueftverrenkung *19 Kongr. d. Deutsche Gesellsch f Chir*, *Centralbl f. Chir*, 1890

Hofmeister, F . Coxa vara, eine typische Form der Schenkelhalsverbiegung. *Beitr. z Klin. Chir*, *7·245, 1894.*

Howorth, M B.· Slipping of the Upper Femoral Epiphysis. *J. Bone & Joint Surg*, *1*:569, 1948.

Howorth, M B · Congenital Dislocation of Hip. *Ann. Surg* *125*:216, 1947.

Howorth, M. B Slipping of the Upper Femoral Epiphysis *Surg*, *Gynec. & Obst.*, *73.723, 1941.*

Howorth, M. B , and Smith, H W.: Congenital Dislocation of Hip Treated by Open Operation, Report of 72 Cases *J Bone & Joint Surg*, *14* 299, 1932

Irwin, S T . Separation of Upper Epiphysis of Femur. *Irish J M. Sc.*, pp. 71-81, 1929

Jahss, S. A.: Slipping of Upper Femoral Epiphysis, Treatment in Pre-slipping Stage. *J. Bone & Joint Surg*, *15*.477, 1933.

Jansen, M Large Brain, Wide Pelvic Girdle and Outstanding Number of Hip Anomalies in Man (Coxa Vara, Coxa Fracta, Coxa Plana, Coxa Valga, Slipping Epiphysis, Malum Coxae). *J Bone & Joint Surg*, *11* 461, 1929.

Jones, (Sir) R , and Lovett, R. W. *Orthopedic Surgery.* New York. William Wood & Company, 1929

Key, J. A.: Epiphyseal Coxa Vara or Displacement Capital Epiphysis of Femur in Adolescence. *J. Bone & Joint Surg*, *8*.53, 1926

Kidner, F. C : Comparative Analysis of Results of Open and Closed Reductions in Congenital Dislocation of Hip *J. Bone & Joint Surg*, *17:25*, *1935.*

Colonna, P C Arthroplastic Operation for Congenital Dislocation of Hip, Two-stage Procedure *Surg, Gynec & Obst*, *63*.777, 1936.

Colonna, P C. Congenital Dislocation of Hip in Older Subjects; Based on Study of 66 Open Operations. *J Bone & Joint Surg*, *14* 277, 1932.

Colonna, P C Fractures of Neck of Femur in Children. *Am. J. Surg*, *6*:793, 1929.

Compere, E L Shelf Operation for Congenital Dislocation of Hip. *Am. J. Surg.*, *43*.404, 1939

Compere, E L, and Schnute, W. J.: Treatment of Congenital Dislocation of Hip *J. Bone & Joint Surg.*, *28* 555, 1946

Compere, E L, Garrison, M., and Fahey, J. J · Deformities of Femur Resulting from Arrestment of Growth of Capital and Greater Trochanteric Epiphyses. *J Bone & Joint Surg*, *22* 909, 1940

Crego, C H, Jr Use of Skeletal Traction as Preliminary Procedure in Treatment of Early Congenital Dislocation of Hip *J. Bone & Joint Surg.*, *21* 343, 1939.

Danforth, M S Treatment of Legg-Calvé-Perthes Disease without Weight-bearing. *J. Bone & Joint Surg*, *16* 516, 1934

Dega, W Ricerche anatomiche e meccaniche siell'anca fetale rivolte a chiarire l'etiologia e la patogenesi della lussazione congenital *Chir d org. di movimento*, *18*:425, 1933-34.

De Santo, D A, and Colonna, P C: Embryology of the Hip Joint; Preliminary Observations. *Arch Surg*, *39* 448, 1939

Dickson, F D Shelf Operation in Treatment of Congenital Dislocation of Hip. *J. Bone & Joint Surg*, *17* 43, 1935

Dickson, F D Operative Treatment of Old Congenital Dislocation of Hip *J. Bone & Joint Surg.*, *6* 262, 1924.

Drehmann, F Zur Frage der Spontanheilung der angeborenen Hufverrenkung. (Eine rontgenologische Studie) *Ztschr f Orthop*, *69*.410, 1939.

Duncan, G A Congenital Coxa Vara Occurring in Identical Twins. *Am J. Surg*, *37*:112, 1937

Ellis, V H Adolescent Coxa Vara *Lancet*, *1*:1440, 1935.

Epstein, B Laminography through Plaster Casts in Post-reduction Roentgenography of Congenital Dislocation of the Hip *J Bone & Joint Surg*, *30*.778, 1948.

Fairbank, H. A. T Late Results of Treatment of Congenital Dislocations of the Hip *Brit. J. Surg*, *10* 24, 1922-23

Farkas, A Mechanics of Formation of "Secondary Acetabulum" in Congenital Dislocation of Hip *J Bone & Joint Surg*, *20*.885, 1938.

Farrell, B P, and Howorth, M B. Open Reduction in Congenital Dislocation of Hip. *J. Bone & Joint Surg*, *17* 35, 1935

Farrell, B P, Von Lackum, H L., and Smith, A. deF.· Congenital Dislocation of Hip; Report of 310 Cases Treated at New York Orthopaedic Dispensary and Hospital *J. Bone & Joint Surg*, *8* 551, 1926

Ferguson, A B, and Howorth, M. B Coxa Plana and Related Conditions at Hip *J. Bone & Joint Surg*, *16* 781, 1934

Ferguson, A B, and Howorth, M B Slipping of Upper Femoral Epiphysis, Study of 70 Cases *J A.M A*, *97* 1867, 1931.

Foley, W B. Treatment of Slipped Upper Femoral Epiphysis, President's Address. *Proc. Roy Soc Med*, *39*.201, 1946

Forrester-Brown, M F Lorenz Bifurcation Osteotomy for Irreducible Dislocation of Hip *Proc. Roy Soc Med*, *31*.454, 1938

Freiberg, A H. The Evolution of Osteochondritis Deformans Coxae Juvenilis. *J A.M A*, *67* 658, 1916

Freiberg, J A Etiology, Pathology, and Diagnosis of Congenital Dislocation of Hip *Reg Orthop Surg & Fund Orthop Prob*, *No 11*, 1947

Freiberg, J. A. Early Diagnosis and Treatment of Congenital Dislocation of Hip *J A M.A*, *102*:89, 1934

Gaenslen, F J: Schanz Subtrochanteric Osteotomy for Irreducible Dislocation of Hip *J Bone & Joint Surg*, *17* 76, 1935.

Luetkin, P.: *Epiphysiolysis Capitis Femoris* (Coxa Vara Epiphysarea), with Special Reference to Bloodless Reposition Treatment. *Acta orthop. Scandinav.*, 10:119, 1939.
MacAusland, W. R.: Treatment of Congenital Dislocation of Hip by Open Operation. *Surg., Gynec & Obst.*, 47:697, 1928.
McCarroll, H. R., and Crego, C. H., Jr.: Primary Anterior Congenital Dislocation of Hip. *J. Bone & Joint Surg*, 21:648, 1939.
Mercer, W.: *Orthopaedic Surgery. London: E. Arnold & Company*, 1945.
Middleton, D. S · Studies on Prenatal Lesions of Striated Muscle as Cause of Congenital Deformity; Congenital Tibial Kyphosis; Congenital High Shoulder, Myodystrophia Fetalis Deformans. *Edinburgh M. J.*, 41:401, 1934.
Milch, H.: Internal-Rotation-Brace Treatment of Epiphyseal Coxa Anteverta (Early Epiphyseolysis). *J. Bone & Joint Surg*, 21.752, 1939
Moore, J. R.: Personal Communication.
Moore, R D: Conservative Management of Adolescent Slipping Capital Femoral Epiphysis. *Surg, Gynec. & Obst*, 80.324, 1945
Moore, R D. Aseptic Necrosis of Capital Femoral Epiphysis Following Adolescent Epiphyseolysis *Surg, Gynec. & Obst*, 80.199, 1945.
Moser, E.. Ueber das Ligamentum teres des Hueftgelenks. *Morphologische Arbieten*, (Schwalbe) 2.36, 1893.
Mueller, F A New Primary Position in the Bloodless Treatment of Congenital Hip Joint Dislocation *J A M A*, 48·282, 1907.
Nordenson, N G: Sur la vascularisation de la tête du fémur par la voie du ligament rond fémoral *Lyon chir*, 35.178, 1938
Ollerenshaw, R. Femoral Neck in Childhood, President's Address. *Proc. Roy. Soc. Med*, 32 113, 1938
Paci, A Quarto contributo alla cura razionale della lussazione iliaca congenita del femore con nuovo metodo. *Arch. di ortop*, 9 401, 1892, *10*:1, 1893
Peabody, C W.· Subtrochanteric Osteotomy in Coxa Vara. *Arch. Surg*, *46*:743, 1943.
Platt, H.: Congenital Dislocation of Hip (Robert Jones Memorial Lecture) *Brit. J. Surg*, *30* 291, 1943
Phemister, D B Aseptische Knochennekrose bei Frakturen, Transplantationen, und Gefassverschlussen. *Ztschr. f. orthop Chir*, *55* 161, 1931.
Ponseti, I.· Pathomechanics of Hip after Shelf Operation. *J. Bone & Joint Surg.* *28* 229, 1946
Ponseti, I Causes of Failures in Treatment of Congenital Dislocation of Hip *J. Bone & Joint Surg*, *26* 775, 1944
Putti, V · Early Treatment of Congenital Dislocation of Hip *J. Bone & Joint Surg*, *11*:798, 1929
Rabinowitz, M S. Slipping of Upper Femoral Epiphysis *J Bone & Joint Surg*, 22.992, 1940
Reich, R S.· Bifurcation Operation for Treatment of Irreducible Dislocation of Hip Joint *J. Bone & Joint Surg*, 7.598, 1925
Ridlon, J. Congenital Dislocation of the Hip. *Surg Clin*, *1*.271, 1917.
Rogers, S P.. Method for Determining Angle of Torsion of Neck of Femur. *J Bone & Joint Surg*, *13* 821, 1931.
Scaglietti, O.. Indirizzi odierni nel trattamento della lussazione congenita dell-anca. *Chir. d. org di movimento*, *25*.308, 1940
Schaefer, R L, and Purcell, F. H: Juvenile Osteochondreal Hypothyroidism. *Am. J Surg*, *54*.589, 1941
Schanz, A · Disturbances in Gait after Fracture of Neck of Femur. *Deutsche med. Wchnschr.*, *51* 730, 1925.
Schwarz, E. Eine typische Erkrankung der oberen Femurepiphyse. *Beitr z. klin. Chir*, 93.1, 1914
Severin, E. Arthrograms of Hip Joints of Children. *Surg, Gynec. & Obst*, 72.601, 1941
Severin, E: Contribution to Knowledge of Congenital Dislocation of Hip Joint, Late Results of Closed Reduction and Arthrographic Studies of Recent Cases. *Acta chir Scandinav*, (*supp. 63*) *84.1*, *1941*.
Severin, E.. Arthroplasty of Hip, New Method *J Bone & Joint Surg*, *21* 304, 1939

Kingsley, P C, and Olmstead, K. L.. *A Study to Determine the Angle of Anteversion of the* Neck of the Femur *J Bone & Joint Surg*, *30-A*[3].681, 1943

Klein, A, Joplin, R J, and Reidy, J A. Treatment of Slipped Capital Femoral Epiphysis. *J A M A*, *136* 445, 1948

Klein, A, Joplin, R J, and Reidy, J A: Treatment in Cases of Slipped Capital Femoral Epiphysis, at Massachusetts General Hospital. *Arch. Surg*, *46*.681, 1943

Kleinberg, S Slipping of the Upper Femoral Epiphysis. Joint Meeting of the American, British and Canadian Orthop. A., June 3, 1948 *J. Bone & Joint Surg.*, (Brit. number) *30-B* 569, 1948

Kleinberg, S Incipient Epiphyseolisthesis of Hip, Its Diagnosis and Treatment. *Am. J. Surg*, *72*.190, 1946

Kleinberg, S. Aseptic Necrosis of Femoral Head Following Traumatic Dislocation; Report of 2 Cases *Arch Surg*, *39* 637, 1939.

Kleinberg, S, and Buchman, J. Operative versus Manipulative Treatment of Slipped Femoral Epiphysis, with Description of Curative Operation. *J.A.M.A.*, *107*:1545, 1936.

Kleinberg, S, and Friedman, E. Observations on Vascularity of Ligamentum Teres, Report of Microscopic Findings in Legg-Perthes Disease and Epiphyseal Slipping (5 Cases). *Bull Hosp Joint Dis*, *1*.72, 1940

Kleinberg, S, and Lieberman, H S: Acetabular Index in Infants in Relation to Congenital Dislocation of Hip *Arch Surg*, *32* 1049, 1936

Kolodny, A Architecture and Blood Supply of Head and Neck of Femur and Their Importance in Pathology of Fractures of Neck *J Bone & Joint Surg*, *7*.575, 1925.

Konde, W N Congenital Subluxation of the Coxofemoral Joint in the German Shepherd Dog. *North American Veterinarian*, *28* 595, 1947

Krida, A. New Departure in Treatment of Congenital Dislocation of Hip. *J. Bone & Joint Surg*, *13* 811, 1931

Krida, A Congenital Dislocation of Hip Joint *Am J Surg*, *6* 185, 1929

Krida, A Congenital Dislocation of Hip, Effect of Anterior Distortion, Procedure for its Correction *J. Bone & Joint Surg*, *10* 594, 1928.

Lange, F. Come possono essere migliorati i risultati finali del trattamento della lussazione congenita dell'anca? *Arch di ortop*, *49* 273, 1933.

Lange, F Die angeborene Hueftverrenkung *Munchen med Wchnschr*, *75*:2001, 1928.

Lange, F Die unblutige Behandlung der angeborenen Hueftgelenksverrenkung. *Munchen med Wchnschr*, *51* 872, 1904

Langer, C Ueber das Gefaessystem der Roehrenknochen *Denkschr Wein. Akad*, *36*·1, 1876

Le Damany, P Congenital Luxation of the Hip *Am J Orthop Surg*, *11*.541, 1913-14

Le Damany, P Die angeborene Hueftgelenksverrenkung Ihre Ursachen, Ihr Mechanismus, Ihre anthropologische Bedeutung *Ztschr f. orthop Chir.*, *21*.129, 1908

Legg, A T Legg-Perthes Disease, with Special Reference to Prognosis and Treatment *Am. J Surg*, *6* 793, 1929

Legg, A T End Results of Coxa Plana *J Bone & Joint Surg.*, *9* 26, 1927

Legg, A T.. An Obscure Affection of the Hip Joint *Boston M. & S J*, *162* 202, 1910

Leveuf, J Primary Congenital Subluxation of Hip *J Bone & Joint Surg*, 29.149, 1927

Leveuf, J B, and Bertrand, P *Luxations et subluxations congenitales de la hanche, leur traitement base sur l'arthrographie* Paris G Doin, 1946.

Levy, L J, and Girard, P M Legg-Perthes Disease, Comparative Study of Various Methods of Treatment *J Bone & Joint Surg*, *24* 663, 1942

Lippmann, R K Pathogenesis of Legg-Calvé-Perthes Disease Based upon the Pathologic Findings in a Case. *Am J Surg*, *6*.785, 1929

Lorenz, A. Ueber die Behandlung der irreponiblen angeborenen Hueftluxationen und der Schenkelhalspseudarthrosen mittels Gabelung (Bifurkation des oberen Femurendes). *Wien klin. Wchnschr.*, *32* 997, 1919

Lorenz, A. Die blutige Reposition der angeborenen Heuftverrenkung (Luxatio coxae congenita) *Centralbl f Chir*, *22* 391, 1895

Ludloff, K. The Open Reduction of the Congenital Hip Dislocation by an Anterior Incision *Am J. Orthop Surg*, *10* 438, 1913.

Bone Tumors and Their Treatment

MURRAY M. COPELAND, M.D. AND
CHARLES F. GESCHICKTER, M.D.

EMBRYOGENESIS OF BONE

A BRIEF SUMMARY of the embryonic processes concerned in the formation of bone seems pertinent to a better understanding of the classification of bone tumors.

Most benign and malignant lesions of bone develop during adolescence, when the tissues at or behind the epiphyseal line are extremely sensitive to abnormal changes. Embryologic processes occurring in this zone include cartilaginous growth, the resorption and vascularization of cartilage which has undergone calcification, ossification of endosteal and periosteal fibrous tissue, and the subsequent development of cancellous and compact cortical bone, through revascularization and reformation of both the periosteal and endosteal bone.

In most of the skeleton where cartilage precedes bone, the embryonal connective tissue is transformed into small, fetal cartilage cells, ultimately giving rise to adult cartilage which calcifies. The osteoblasts of the perichondrium arise from the periosteal fibroblasts, thus forming the cortex. Centrally the cancellous bone replacing cartilage arises from the endosteum. The endosteum, along with an ingrowth of blood vessels, penetrates the eroded cartilage to lay down the spongy bone

Where membranous bones arise (skull) a direct ossification of intramembranous connective tissue occurs at one or more central points. The spindle cells of the connective tissue develop into osteoblasts which lay down spicules of bone. Both enchondral bone and membranous bone have a common process of ossification from this point.

Ossification in its final formative phase utilizes a complex mineral salt of calcium carbonate and phosphate which remains readily available in the bone should the needs of the body require it. Such lability of the osseous structure is further characterized during the resorptive phase of bone growth and repair by a vascular connective tissue in which osteoclasts (giant cells) are prominent.

In the development of tumors, (1) cartilaginous growth is represented by chondromas, etc.; (2) vascularization of cartilage and resorptive changes of the osseous structure are related to giant cell tumor, bone cysts, and certain of the osteogenic sarcomas, (3) ossification (membranous type) is related to osteomas, ossifying fibromas, sclerosing osteogenic sarcomas, etc.; (4) combinations of the processes above are reflected in the development of osteochondroma, chondroblastomas, etc; (5) the marrow, vessels, and overlying fibrous tissue give rise to

Shands, A R, Jr.. *Handbook of Orthopaedic Surgery.* Ed. 3 St. Louis: C. V. Mosby Company, 1948

Sherman, M. S, and Phemister, D. B.. Pathology of Ununited Fractures of Neck of Femur. *J Bone & Joint Surg*, 29 19, 1947.

Smith-Petersen, M N · Treatment of Malum Coxae Senilis, Old Slipped Upper Femoral Epiphysis, Intrapelvic Protrusion of Acetabulum, and Coxa Plana by Means of Acetabuloplasty *J. Bone & Joint Surg*, *18* 869, 1936

Snodgrass, L. E: Perthes' Disease *J Bone & Joint Surg*, *14*.314, 1932.

Soutter, R., and Lovett, R W · Congenital Dislocation of Hip *J.A.M.A.*, *82*:171, 1924.

Stewart, S F. Physiological Treatment of Congenital Dislocation of Hip. *J. Bone & Joint Surg*, *17* 11, 1935

Stewart, W J Aseptic Necrosis of Head of Femur Following Traumatic Dislocation of Hip Joint, Case Report and Experimental Studies. *J. Bone & Joint Surg*, *15*:413, 1933.

Stockard, C. R, Anderson, O D, and James, W. T.. Genetic and Endocrinic Basis for Differences in Form and Behavior as Elucidated by Studies of Contrasted Pure-line Dog Breeds and Their Hybrids *Am Anatomical Memoirs, No. 19*, Wistar Institute, 1941

Strayer, L M, Jr. Embryology of Human Hip Joint *Yale J Biol & Med.*, *16*:13, 1943

Taylor, V J Displacement of Upper Femoral Epiphysis, Report of 23 Cases. *Brit. M. J*, 2 1003, 1932

Tucker, F R · Arterial Supply to the Femoral Head and its Clinical Importance. *J. Bone & Joint Dis* (British Edition), *31* 82, 1949.

Turner, W. G Notes on the Pathological Anatomy of Congenital Hip Dislocation. *Am J Orthop Surg.*, *6*.652, 1908, 1909.

Vogt, E C Congenital or Infantile Dislocation of Hips *Am J Roentgenol*, *37*.21, 1937.

Waldenstrom, H Slipping of Upper Femoral Epiphysis. *Surg, Gynec. & Obst.*, *71*.198, 1940

Waldenstrom, H. First Stages of Coxa Plana. *J Bone & Joint Surg* *20*.559, 1938.

Waldenstrom, H. Die operative Behandlung von Tuberkulose in Schenkelhals. *Ztschr. f. orthop Chir*, *22* 581, 1908

Walmsley, T A Note on the Retinaculum of Weitbrecht. *J Anat*, *51* 61, 1917.

Wardle, E N.. Etiology and Treatment of Slipped Epiphysis of Head of Femur. *Brit J. Surg*, *21* 313, 1933.

Wen [illegible] of the Hip. *Am. J.* [illegible]

Wen [illegible] Hueftgelenksverrenkung *Ztschr f orthop Chir*, *13*·765, 1904.

West, W. K Treatment of Slipped Upper Femoral Epiphyses. *South. M J*, 35.1082, 1942.

Whitman, R Further Observations on Operative Treatment of Legg-Perthes Disease *Am J. Surg*, *6* 791, 1929

Wilson, P D Conclusions Regarding Treatment of Slipping of Upper Femoral Epiphysis *S Clin North America*, *16*:733, 1936

Wilson, P D Treatment of Slipping of Upper Femoral Epiphysis with Minimal Displacement *J Bone & Joint Surg.*, *20*.379, 1938.

Wolcott, W E. Circulation of Head and Neck of Femur, Its Relation to Nonunion in Fractures of Femoral Neck *J A M A*, *100* 27, 1933

Zadek, I Congenital Coxa Vara *Arch Surg*, *30* 62, 1935

Zemansky, A P, Jr, and Lippmann, R K Importance of Vessels in Round Ligament to Head of Femur During Period of Growth, and Their Possible Relationship to Perthes' Disease *Surg, Gynec. & Obst*, *48* 461, 1929

Zemansky, A. P., Jr. Pathology and Pathogenesis of Legg-Calvé-Perthes Disease (Osteochondritis Juvenilis Deformans Coxae). *Am. J Surg*, *4*.169, 1928

tilaginous connective tissue in the skeleton. These neoplasms are most frequent near the ends of the long bones of patients between the ages of 10 and 25 years. The other sites of importance are the bones of the thoracic cage and the small bones of the foot and hand. The distinctive diagnostic features are the pedicle of normal bone protruding from the bone cortex and the rim of cartilage overlying it. A similar structure may be seen microscopically. The roentgenogram demonstrates the compact differentiated outgrowth of bone and an overlying cartilaginous cap flecked with calcium (Figs. 1A and 1B). Cases of single osteo-



FIG 1A.—Roentgenogram showing an exostosis of pedicle type at the site of muscle attachment to the upper tibia Note the widened metaphyseal region near the outgrowth and the extension of the pedicle in the direction of the pull of the lower leg muscles.

chondromas without symptoms frequently go unnoticed They may be left [illegible] roentgenographic examination, since [illegible] nge, particularly after the age of 30 [illegible] an exostosis represents a failure in the accurate approximation of tendon and cortex. Simple excision usually suffices to cure the osteochondromas which produce pain or dysfunction.

In hereditary or *multiple osteochondromas,* the regions most frequently and

a group of tumors of nonosseous origin which invade bone; (6) resorptive phases of bone activity may also be seen when the mineral is depleted because of endocrine disturbances or other metabolic changes.

Throughout life foci of potential growth persist at points where transitions of tissue are found, and represent a possible source of tumor formation in bone.

The classification of bone tumors based on the relation of bone development to subsequent tumor formation and to the different structural elements of the skeleton separates the tumors into specific types, each of which follows a definite course. A survey of these groups reveals more accurately the effect of treatment, and thus prognosis is placed on a sound basis.

TABLE I

CLASSIFICATION OF BONE TUMORS *

TUMORS OF OSSEOUS ORIGIN

Cartilaginous	*Osseous*	*Resorptive*
Osteochondroma (solitary and multiple)	Osteomas and ossifying fibromas of skull and jaws	Bone cyst
Chondroma	Osteoid osteoma	Diffuse osteitis fibrosa (parathyroidism)
Chondroblastoma, benign and malignant	Osteogenic sarcoma, sclerosing and osteolytic	Fibrous dysplasia, polyostotic or monostotic
Chondrosarcoma, primary or secondary	Parosteal ossifying fibromas and myositis ossificans	Giant cell tumor

TUMORS OF NONOSSEOUS ORIGIN

Marrow and Haversian Systems	*Metastatic Deposits*	*By Inclusion or Direct Invasion*
Ewing's sarcoma	Carcinoma of prostate, breast, kidneys, etc	Chordoma
Multiple myeloma	Metastatic lymphomas and sarcomas	Angioma, angiosarcoma
Chloroma and leukemia of bone		Fibroma and fibrosarcoma, fascial or nerve sheath
Reticulo-endotheliosis		Myosarcoma
Xanthomas and granulomas of bone		

* After Geschickter and Copeland, *Tumors of Bone* Philadelphia J B Lippincott Co, 1949

A brief survey will be given of each group, the treatment used, and, where irradiation seemed of benefit, the physical agent used. No comprehensive rule can be laid down as to whether a tumor process is radiosensitive. Experience has been our best teacher as to the behavior of tumors under radiation by radium, x-rays, or radioisotopes.

TUMORS OF OSSEOUS ORIGIN

It may be said in general that surgery offers the best method of treatment in tumors of this group They are not radiosensitive. Isolated examples may be pointed out in which the growth of the tumor has been affected by irradiation, or where the roentgen rays and gamma rays have been used successfully as an adjunct to surgery.

CARTILAGINOUS

Exostosis or Osteochondroma. This is primarily a surgical problem when treatment is necessary This is the largest group of benign tumors arising from precar-



A



B

Fig. 2.—Roentgenogram of hereditary deforming chondrodysplasia or multiple exostoses. Note the widening of the metaphyseal regions of the long bones and the tendency to develop outgrowths of osteochondromas. Besides the multiple exostoses the patient has a deficiency in growth of the ulna with shortening of the lower end.

severely affected are those of the forearm and leg, the bones of which may be fused at one point (Figs. 2A and 2B). The prognosis as far as life is concerned is good, but there is no adequate form of treatment except operation for correction of deformities and removal of an osteochondroma causing pain or dysfunction In a few cases with multiple skeletal involvement, secondary malignant change is

Chondroma Chondroma, a common type of central cartilaginous tumor, is



FIG 1B —Photomicrograph of the osteochondroma after operation At the upper margin is adult cartilage which makes up the cap of the osteochondroma Beneath this there is protrusion of normal adult bone enclosing a small amount of marrow. Between the bone and the calcified cartilage is a row of giant cells derived from the bone marrow.

often classified with the benign exostoses or osteochondromas. It occurs in the small bones of the hands and feet, also in the spine, ribs, and sternum. In the small acral bones the tumor composed of radiolucent cartilage appears as a central lesion with rarefaction, visible in the roentgenogram as a cystic area, within a shell of cortical bone Histologically a central area of cartilage with orderly arrangement of cells is usually seen (Figs. 3A and 3B). In some chondromas, myxoma may be present in varying amounts The lesions are rarely multiple and occasionally affect long bones. In deciding whether a particular chondroma is to be treated from the benign or malignant standpoint, the location, not the pathologic

changes, is given primary consideration. Lesions in the small bones of the hands and feet may be looked on as benign and curable by *thorough extirpation* (curettage and cauterization). Only rarely has a central chondroma of the phalanges, metacarpals, or metatarsal bones shown malignant propensity. True chondromas of large size occurring about the sternum or in the long bones must be looked upon as potentially malignant. They should be removed if possible. Roentgen or teleradium therapy has been of benefit in retarding the growth in a few cases. One patient survived 18 years after diagnosis, with repeated series of roentgen treatments.

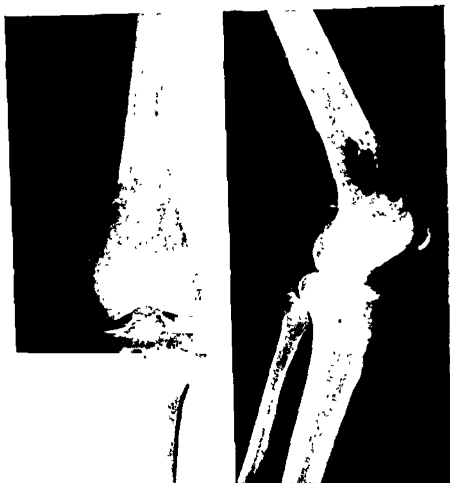


FIG. 4A—Roentgenogram of a benign chondroblastoma arising at the epiphyseal line and extending for some distance into the metaphysis. Note the multilocular structure of the chondromatous growth, the perforated bone shell, and the periosteal reaction suggesting a malignant character.

Muffucci's syndrome, or dyschondroplasia with hemangiomatosis, is a nonhereditary mesodermal dysplasia. Skeletal development may be retarded on one side or in individual bones, principally the bones of the extremities, thoracic cage, pelvis, and vertebrae Multiple central chondromas made up of myxoma and adult cartilage, associated with soft part hemangiomas, are observed in the affected bones. In structure the soft part angiomatous tumors are cavernous to cellular angioblastic tumors in type. The deformities may appear early but become stationary in the



A



B

FIG 3A and B.—Roentgenogram and photomicrograph of the central chondroma of the phalanx successfully treated by curettage and cauterization with 50 per cent zinc chloride followed by alcohol. *Note the orderly arrangement of the cartilage, which is of the adult type.*

Some of these tumors show malignant degeneration which frequently cannot be differentiated from the benign lesions except by histopathologic study. Many investigators classify the malignant variety with the chondrosarcoma group.

This benign or malignant tumor process is not particularly radiosensitive and requires large amounts of irradiation to control it. Radium or roentgen therapy (Coutard method) in the benign lesions following exploration and curettage is recommended, unless the tumor occurs in a bone which can be resected without sacrifice of function. The malignant variety of chondroblastoma has been uniformly fatal despite primary amputation.

VARIETIES OF OSTEOGENIC SARCOMA

Osteogenic sarcoma includes several subvarieties of malignancy which may arise either subperiosteally or centrally in the skeleton from the bone-forming

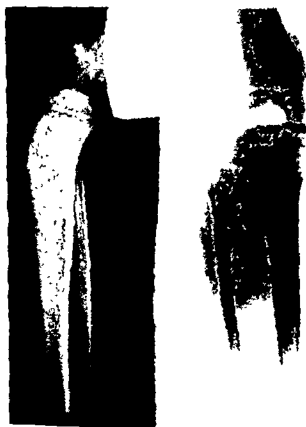
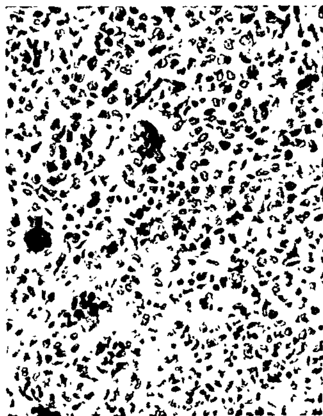


FIG 5A.—Roentgenogram showing an advanced case of primary chondrosarcoma in the upper tibia. Note the translucent character of the periosteal growth flecked with calcium and the mottled areas in the tibia beneath. There is absence of marked medullary or cortical involvement

tissues and produce bone, cartilage, osteoid material, or preosseous connective tissue. These malignant tumors displace and disrupt the pre-existing bone. They are characterized in the roentgenogram by varying degrees of bone destruction, new bone formation, and periosteal reaction. When bone formation predominates, the tumors are referred to as sclerosing or osteoblastic osteogenic sarcoma. When

early twenties. Trivial injuries may cause fractures through the chondromatous areas. The patients present marked bone and soft part deformities, occasionally requiring amputation of an extremity for comfort, owing to loss of function. Twenty-two cases have been reported to date.

Chondroblastoma—Benign and Malignant. Chondroblastoma is a rare osteolytic variant of chondroblastic tissue origin sometimes called cartilaginous giant-cell tumor. It arises from a proliferation of cartilage at the epiphyseal line, and usually occurs between the ages of 10 and 20 years. It is most frequently found about the upper end of the tibia, the lower end of the femur, and the upper end of the humerus. Symptoms of pain, tumor, and dysfunction prior to operation average five months in duration.



In the roentgenogram there is a characteristic mottled, cystic area of bone destruction, with expansion of the bone shell and usually some periosteal reaction Not infrequently the tumor bears a marked similarity to giant cell tumor (Fig. 4A). Microscopically, one sees masses of young and adult cartilage with areas of uncalcified hyalin matrix. The tumor has areas of marked vascularity. Near the vascular areas and about the periphery of the cartilage, numerous giant cell osteoblasts are seen (Fig. 4B).

The patient usually suffers pain, swelling, and lameness in the affected part. The symptoms are of increasing severity and vary from six weeks to six months in duration before a specialist is consulted. Trauma is usually coincidental in exacerbating the symptoms and often is not of etiologic significance. There may be a mild degree of fever and leukocytosis. Tenderness, swelling, and limitation of motion are often apparent on physical examination. Skin changes and regional adenopathy are not present in early cases. The tumor tends to metastasize to the lungs by way of the blood stream rather than via the lymphatics.



FIG. 6A.—Roentgenogram of the lower end of the femur, showing chondrosarcoma arising in a central chondromatous lesion The condition caused symptoms for several years Note the trabeculae *interspersed with calcification, the tumor invasion of the cortex with a resultant* periosteal reaction. The persistence of the old chondromatous tumor in the center of the bone is to be noted.

Adequate roentgenologic examination and surgical biopsy under the tourniquet are the only definitive diagnostic procedures. Osteogenic sarcomas are not cured by radiation. Radical surgery is the treatment of choice. The five year survivals vary from 10 to 25 per cent.

Primary chondromyxosarcoma arises primarily in young patients (aged 14 to 21 years) and at the sites where tendons insert directly into the bone. The favorite sites are about the knee, in the lower femur or upper tibia, also at the shoulder and pelvic girdles. The neoplasm is a form of periosteal osteogenic sarcoma and is composed of well developed tumor cartilage, myxomatous tissue, some ossification, and areas of cystic destruction. In the roentgenogram it appears as a subperiosteal shadow streaked with calcified spicules. It does not involve the cortex until late in the disease, when it causes bone destruction (Figs. 5A and 5B). All surviving patients have had amputation performed. Irradiation has little or no influence on the result, but it relieves pain in many instances and reduces soft part swelling Permanent cures in this group average 15 per cent.

bone destruction predominates, the tumors are highly vascular and are referred to as osteolytic or telangiectatic osteogenic sarcoma. When cartilage rather than bone formation or destruction predominates, the tumors are called chondrosarcomas. Primary chondrosarcoma refers to a malignant tumor which affects pre-existing normal osseous structures. Secondary chondrosarcoma refers to similar tumors which arise in pre-existing osteochondromas or chondromas.

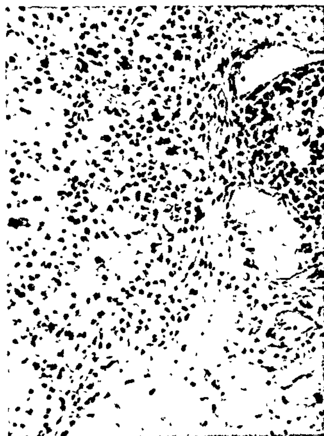


Fig '
cartil
are s
show capsule formation Note the large vascular spaces

All forms of osteogenic sarcoma are more frequent in the long bones especially in the ends of the femur, tibia, and fibula about the knee joint. They tend to occur in the adolescent or postadolescent period. Sclerosing osteogenic sarcoma and primary chondrosarcoma are largely limited to this age group Osteolytic and

genogram therefore shows increased density, rarefaction, or mottling, and the periosteal zone near the tumor infiltration shows lipping and elevation due to the density of reactive bone formation and the disease beneath it.



FIG 7A.—Roentgenogram of a preossifying variant of sclerosing osteogenic sarcoma arising on the lateral aspect of the tibia. The tumor mass is seen arising subperiosteally, causing a dense extracortical shadow. In the lateral view a definite sunray appearance of the soft part shadow is seen. The cortex and marrow cavity beneath it are invaded and sclerosed.

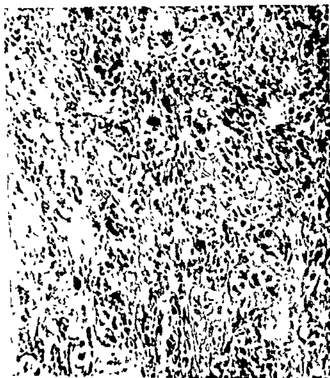


FIG. 7B.—Microscopic section showing formation of definite but irregular osteoid spicules surrounded by a profusion of malignant osteoblasts. Many abortive osteoblasts give the appearance of mononuclear giant cells. Some areas of the tumor osteoblasts show definite but early osteoid material surrounding the cells.

Secondary chondrosarcoma arises on the basis of a pre-existing chondroma or osteochondroma. It occasionally develops as a complication in Paget's disease of bone or hereditary chondrodysplasia. Most of the patients are between the ages of 35 and 55 years. The upper humerus, ribs, and femur are frequent sites of origin.

In the roentgenogram it is most easily diagnosed where a portion of the primary lesion still remains and where the superimposed malignant change appears as a fuzzy infiltrating periosteal shadow flecked with calcium deposits. Destruction of the cortical bone follows, occasionally with pathologic fracture.



FIG. 6B.—Photomicrograph revealing areas of adult tumor cartilage undergoing calcification with peripheral proliferation of connective tissue which in secondary chondrosarcoma soon takes on a myxomatous character. Histologically, a secondary chondrosarcoma is at times difficult to distinguish from primary chondrosarcoma and from the closely related osteochondromas and chondromyxomas

Microscopically, the tumor is composed of cartilage, large amounts of myxomatous tissue, calcified cartilage, and proliferating connective tissue elements (Figs. 6A and 6B). The age of onset is much later than in primary chondrosarcoma, usually over 25 years. Irradiation may be of benefit as an adjunct to surgery. The relative benignity of the lesion however plays a more important role in the cure of this tumor process by resection or amputation with or without irradiation. Twenty-six per cent of patients survive five years or more.

formation of cancellous bone which normally follows in the wake of calcified cartilage.

Clinically, the tumor is usually observed about one year after the beginning of symptoms. It has a wide age distribution, but is most frequent in young adults. The tumor has an unusual tendency to involve the shaft and is frequently complicated by a pathologic fracture. The roentgenograms may be hard to interpret and are often confused with benign bone cyst, giant-cell tumor, metastatic carcinoma, and Ewing's sarcoma. The distinguishing features in the roentgenogram



FIG 8B.—The gross specimen of the tibia shown in Fig. 8A reveals the tumor to be located in the metaphysis of the upper tibia, the majority of the neoplasm is within a shell of cortical bone and arising from cancellous bone. The cortex is perforated at one point and the tumor is seen infiltrated beneath the periosteum.

are the melting away and perforation of the bone shell at an early stage when the lesion is asymmetrically located, the presence of a periosteal reaction, and the slight degree of cortical expansion. In advanced cases osseous destruction leaves little doubt of malignant change in the bone. Microscopically, large spindle cells and large abortive osteoblasts with numerous mitotic figures and small amounts of osteoid tissue are seen (Figs. 8A to 8C)

The tumor is not sensitive to roentgen rays or radium. Amputation only has been effective in giving five year survivals (16 per cent).

Osteoma and Ossifying Fibromas These neoplasms are due to direct ossification

OSSEOUS

Osteoblastic Osteogenic Sarcoma. This tumor occurs as a highly differentiated form of osteogenic sarcoma. Fibrous elements may predominate microscopically, but proliferation of malignant osteoblasts and new bone formation are usually seen with rare islands of tumor cartilage. This tumor occurs most frequently between the ages of 15 and 25 years and is usually situated in either the lower end of the femur or the upper end of the tibia. Other locations are the upper humerus, ribs, vertebrae, and pelvis.



FIG 8A –Roent ... tibia The cancellous and ... ll There is

The roentgenographic picture is characterized by dense, radiating new bone in the periosteal zone, giving a "sunray" appearance. Later the medullary cavity is obliterated by tumor bone with some secondary destruction of the cortex. Histologically, the chief diagnostic features are large malignant osteoblasts with a conglomerate scattering of osteoid substance (Figs 7A and 7B).

Cell differentiation of the tumor process apparently plays an important role in the prognosis Radical extirpation by amputation or resection appears to be the procedure of choice. The lesion is not radiosensitive Cures have been achieved in 21 per cent of the cases

Osteolytic Osteogenic Sarcoma. This destructive tumor arises in the region of the marrow cavity in the shaft of the long bones It seems to be related to the

Osteoid Osteoma. Osteoid osteoma is a small, rarefying lesion found in enchondral bone which is composed of vascular fibrous tissue and proliferating fibroblasts in which trabeculae of newly formed osseous tissue are noted. The lesion usually does not exceed 1 cm. in diameter. The patients are usually young adults or adolescents. Localized pain is often the primary complaint and may be associated with tenderness without fever or leukocytosis. The lesion is chronic and may persist for a period of months to one or more years. In the roentgenogram, a dense, sclerosing, opaque zone about a small oval or rounded area of . . . intracortical lesion or in the . . . of the hands, feet, vertebrae, and shafts of the long bones.



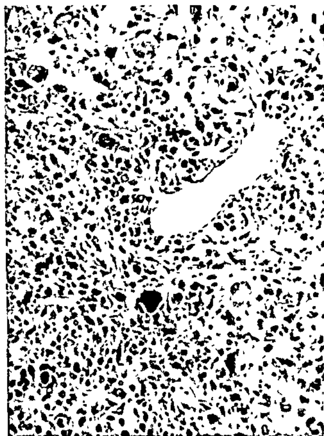
Fig. 9 –Osteoid osteoma occurring intracortically in the shaft of the tibia. The roentgenogram shows an intracortical area of rarefaction with extensive perifocal sclerosis. The rarefied areas seldom exceed 1 cm in diameter.

The two principal theories on the nature of osteoid osteoma at this time are: (1) that the lesion is a primary neoplastic process of bone; (2) that the process is inflammatory in origin. Another unverified interpretation holds that osteoid osteoma represents a healing area about a bone infarction of minute size.

Excision will cure these small, benign lesions.

Parosteal Ossifying Fibromas and Myositis Ossificans. (1) Parosteal osteoma is a rare lesion composed of ossifying fibrous tissue, suggesting a circumscribed myositis ossificans. It differs, however, in that it involves the neighboring bone in many instances, though it may be confined entirely to the soft parts. The roentgenogram reveals an ossifying mass, usually of considerable . . . out . . . A . . . the . . . suggests a cellular myositis ossificans, with bony trabeculae embedded in

in fibrous tissue. These growths usually occur in children or young adults in the frontal or parietal bones of the skull, in the bony walls of the frontal or maxillary sinuses, and in the mandible. They are much more rare than are osteochondromas. The more rapidly growing osteomas are composed of cellular fibrous tissue in which small, round osteoid bodies are formed. The more slowly growing tumors of this type form spongy bone and sometimes ultimately give rise to compact bone, frequently referred to as eburnated osteomas. The roentgenographic findings show a dense mass of new bone, smoothly outlined, with a sharply demarcated base formed by the thickened, slightly depressed inner table of the skull.



When seen in the mandible, the roentgenogram reveals a tumor mass of regular contour projecting from the normal bony structure. The new bone is less dense than the normal bone In the region of the antrum, the affected side shows increased density or cloudiness In most instances, the tumor arises outside the antrum and encroaches on the antral cavity, or pushes downward toward the alveolar border, displacing the teeth downward. These lesions are often complicated by trauma or infection

Osteoma and ossifying fibroma are benign tumors and do not warrant radical or mutilating operations. Simple excision usually suffices to eradicate the disease.

(2) Myositis ossificans may be divided into the traumatic and atraumatic forms arising about the thigh, arm, elbow, neck, and lumbar muscles. Occupation plays little or no role in the case histories studied. Injury is definitely an important factor in 60 per cent of the lesions. The age incidence varies between 10 and 72 years. The earliest physical sign after injury is the development of a soft, compressible mass which soon becomes indurated. Bone may be detected in the



in some cases but is difficult to find microscopically.

roentgenogram within three weeks after the onset of the tumor formation. Small dense areas of ossification soon assume large proportions, forming a large spicule of bone which is usually separated from the shaft of the neighboring bone (Fig. 11A). Many lesions gain their maximal growth in six weeks or more and then, spontaneously, regression is followed by quiescence. Histologically, degeneration of muscle, hyperplasia of connective tissue, and organization of hemorrhage are early findings. Osteoid tissue with marrow spaces, osteoblasts about the spicules of bone, occasional islands of cartilage (30 per cent of cases), and benign myxomatous tissue represent fully developed myositis ossificans (Fig. 11B). Malignant changes may occur, but this is exceedingly rare.

A conservative form of treatment is desirable in the majority of cases, and the lesion may be watched, without treatment, by interval roentgen examinations. Postoperative recurrences are frequent if surgical removal is employed too early

fibrous tissue. The fibroblasts, osteoblasts, and giant cells may be intermingled in areas which suggest osteolytic sarcoma. Close observation of the nuclei, however, reveals the lesion to be benign (Fig 10B). The tumor grows at a slow rate, giving rise to symptoms of tenderness, pain, and ultimate dysfunction. A lump is felt at the onset of the symptoms in the region of tenderness. Malignant changes in the tumor may supervene.



Fig 10A —Roentgenogram of a parosteal osteoma which has many of the characteristics of a sclerosing osteogenic sarcoma There is dense osteoid formation in the soft parts surrounding the femur with some encroachment upon the cortex of the shaft of the femur

Excision is the treatment of choice Where the neighboring bone is invaded, even if the benign character of the tissue is confirmed by microscopic examination, roentgen therapy should be given postoperatively If renewed growth is seen, amputation must be performed because of eventual malignant change in these tumors.

such locations the bone formed does not have the growth tendencies of a neoplasm.

There are instances, however, of extraskeletal ossification which must be regarded as truly neoplastic, and in these malignant changes are ultimately seen. [illegible] have the characteristics of osteogenic sarcoma and [illegible] removed, where possible. They terminate fatally as a rule, in spite of [illegible] excision.

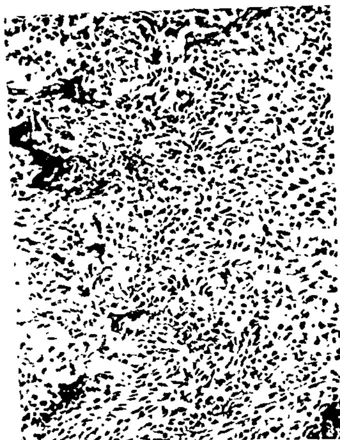


FIG 11B —Photomicrograph showing cellular connective tissue with imperfect osteoid trabeculae and some areas of cartilage observed in the case of circumscribed myositis ossificans shown in Fig. 11A. In some cases laminated bony spicules are seen embedded in angiomatous tissue. Frequently the differential diagnosis between myositis ossificans and forms of osteogenic sarcoma may tax the judgment of the most experienced pathologist.

RESORPTIVE

Bone Cyst. The benign solitary bone cyst is seen in children under the age of 18 years. It usually occurs in the shaft near the upper ends of the humerus, femur, or tibia and runs a protracted and benign course. Pathologic fracture is the only acute phase of the disease and probably the most frequent reason for consulting a physician. The roentgenogram shows a central expanded bone defect, symmetrical and regular in contour. Microscopically, a healing bone reaction is noted

(under six months), or if excision is inadequate. There are isolated cases which have had successful regression of recurrence following therapeutic dosages of roentgen rays. Insufficient experience with the use of ionizing radiations on myositis ossificans prevents any final evaluation of the results obtained.

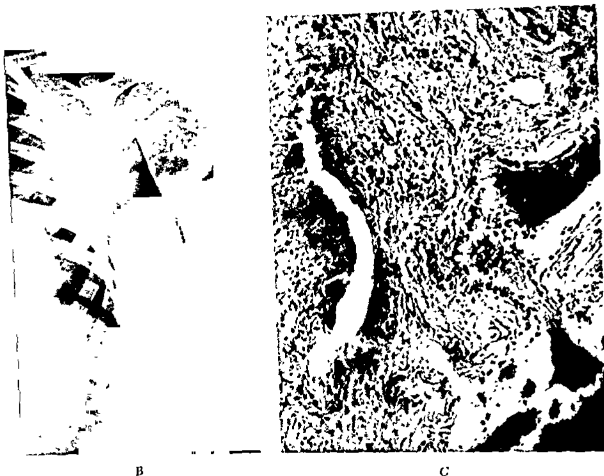


FIG 11A.—Roentgenogram of a typical myositis ossificans. The lesion occurred six weeks after an injury The osseous mass is parallel to the shaft of the femur; it approaches contiguity but does not overlap it.

(3) Myositis ossificans progressiva, a special form of the malady, usually begins in childhood; it affects the spinal muscles primarily. As the name implies, it eventually involves the muscles of the entire skeletal system. Conservative therapy only is indicated. The ultimate outcome is usually fatal.

Extraskeletal Osteogenic Sarcoma. Metaplastic ossification has been described in almost every organ of the body where connective tissue is found. It has been noted in the walls of blood vessels, bladder, kidneys, heart, breast, uterus, and in the soft parts generally. This type of heterologous ossification is often looked on as a reparative process in an area of tissue necrosis where calcium is deposited. In

(2) Polycystic osteitis fibrosa, a multilocular structure, occurs either as a single lesion or with generalized osteitis fibrosa cystica. The cysts occur near the epiphysis on the metaphyseal side, but extend over a considerable area of the bone shaft. The duration of symptoms averages about five months. In the film they appear as an aggregation of small cysts, which have more or less coalesced, giving a polycystic appearance with some expansion of the cortex (Fig. 13). Histologically, there are many small cysts, usually filled with blood and surrounded by giant cells. Varying amounts of fibrous tissue may be seen.



B C

FIG. 12B.—Roentgenogram of a bone cyst on the shaft side of the epiphyseal line in the upper end of the humerus. Note the trabeculated cystic area with expansion of bone shell and progression toward the midshaft region

(Case of Dr. William Tobin, Washington, D C.)

FIG 12C.—Photomicrograph of tissue taken from the wall of the lesion shown in Fig 12B. Note the spicules of osteoid tissue with marked osteoblastic activity, the vascular connective tissue, and the appearance of giant cells bordering on a vascular space.

The prognosis as to life is good in these forms of bone cysts. In the solitary bone cyst of the adult in which symptoms are absent, no treatment is indicated. In the solitary bone cyst of young people, where fracture has occurred and the position of the fragments is satisfactory, simple fixation usually gives a good result. If the lesion is progressive after several months, exploration and curettage, followed by

about the cavity, which may be lined by fibrous tissue (Fig. 12A). It usually is filled with straw-colored fluid or remains of old hemorrhage. Some cysts are trabeculated Spontaneous arrest of the lesion without obliteration of the cavity results in the latent bone cyst. Fracture through the cyst may result in healing



FIG 12A—Roentgenogram of a typical latent bone cyst in the upper metaphysis of the tibia Note the area of bone erosion within the cortical shell There is a slight increase in density of bone about the cystic area indicating a healing bone reaction

Variations in the simple bone cyst may be encountered:

(1) Giant cell variant of the bone cyst, in which the duration of symptoms is found to be shorter and in which the lesion is located invariably near the epiphysis of the bone on the metaphyseal side. This variant is most commonly found in the greater trochanter of the femur and lower radius. In the roentgenogram it is polycystic in character, more subcortical than central, and most frequently trabeculated (Fig. 12B). Microscopically, the walls are lined by fibrous stroma containing variable numbers of giant cells. Hemorrhage is common (Fig. 12C). These lesions stand midway between the typical bone cyst and giant-cell tumor.

(2) Polycystic osteitis fibrosa, a multilocular structure, occurs either as a single lesion or with generalized osteitis fibrosa cystica. The cysts occur near the epiphysis on the metaphyseal *side*, but extend over a considerable area of the bone shaft. The duration of symptoms averages about five months. In the film they appear as an aggregation of small cysts, which have more or less coalesced, giving a polycystic appearance with some expansion of the cortex (Fig. 13). Histologically, there are many small cysts, usually filled with blood and surrounded by giant cells. Varying amounts of fibrous tissue may be seen.



B



C

Fig 12B.—Roentgenogram of a bone cyst on the shaft side of the epiphyseal line in the upper end of the humerus Note the trabeculated cystic area with expansion of bone shell and progression toward the midshaft region

(Case of Dr William Tobin, Washington, D. C.)

Fig 12C.—Photomicrograph of tissue taken from the wall of the lesion shown in Fig. 12B Note the spicules of osteoid tissue with marked osteoblastic activity, the vascular connective tissue, and the appearance of giant cells bordering *on* a vascular space.

The prognosis as to life is good in these forms of bone cysts In the solitary bone cyst of the adult in which symptoms are absent, no treatment is indicated. In the solitary bone cyst of young people, where fracture has occurred and the position of the fragments is satisfactory, simple fixation usually gives a good result. If the lesion is progressive after several months, exploration and curettage, followed by

about the cavity, which may be lined by fibrous tissue (Fig. 12A). It usually is filled with straw-colored fluid or remains of old hemorrhage. Some cysts are trabeculated. Spontaneous arrest of the lesion without obliteration of the cavity results in the latent bone cyst. Fracture through the cyst may result in healing.



FIG 12A.—Roentgenogram of a typical latent bone cyst in the upper metaphysis of the tibia. Note the area of bone erosion within the cortical shell. There is a slight increase in density of bone about the cystic area indicating a healing bone reaction

Variations in the simple bone cyst may be encountered:

(1) Giant cell variant of the bone cyst, in which the duration of symptoms is found to be shorter and in which the lesion is located invariably near the epiphysis of the bone on the metaphyseal side. This variant is most commonly found in the greater trochanter of the femur and lower radius. In the roentgenogram it is polycystic in character, more subcortical than central, and most frequently trabeculated (Fig. 12B). Microscopically, the walls are lined by fibrous stroma containing variable numbers of giant cells. Hemorrhage is common (Fig 12C). These lesions stand midway between the typical bone cyst and giant-cell tumor.

deformity and definite cystic lesions, any one of which may be associated with spontaneous fracture. Less commonly seen is collapse of the vertebra and other skeletal disturbances. Urinary calculi *commonly* develop, leading to renal colic and hematuria. The blood serum calcium varies from 12 to as high as 23 mg. per



FIG. 14.—Roentgenogram of bone lesions in the tibia and fibula, associated with hyperparathyroidism. Note the definite rarefaction of the bones which is due to depletion of calcium and phosphorus. The fibula shows marked cystic destruction in its upper portion with expansion of the bone shell and without healing bone reaction. The shaft of the tibia reveals a large cystic area with erosion of the cortex.

100 cc., while the plasma phosphorus may be depressed as low as 1 or 2 mg. per 100 cc. of blood. The endocrine basis for the various changes seen in this disease have been well substantiated. Parathyroid adenomas are being demonstrated in increasing numbers of cases. In the differential diagnosis of osteitis

chemical cauterization, is indicated. Bone chips or crushing of the bone shell may be used to obliterate the cavity In the acute bone cyst (giant cell variant) moderate amounts of roentgen therapy given in divided doses is adequate treatment if the diagnosis is certain. Should irradiation fail, operative interference may be necessary. Primary curettage and cauterization yield excellent results. Irradiation followed by surgical procedures gives less satisfactory healing in the aggressive bone cysts



Fig. 13.—Roentgenogram of the upper end of the radius showing a variant of bone cyst known as polycystic osteitis fibrosa The roentgenogram shows an aggregation of small cysts which have more or less coalesced, involving the upper third of the radius At one point there is definite expansion of the bone shell Note the erosion of the cortex Histologically, these lesions reveal varying amounts of fibrous tissue with small cysts usually filled with blood and surrounded by giant cells

(3) Multiple osteitis fibrosa cystica is a generalized demineralization of bones due to hyperparathyroidism Bone involvement is most pronounced in the pelvis, spine, and long bones. The calcium in the serum is usually elevated. This disease occurs at any age from childhood to late adult life The depletion of calcium and phosphorus in the bones results in definite rarefaction of the bones with bending

deformity and definite cystic lesions, any one of which may be associated with spontaneous fracture. Less commonly seen is collapse of the vertebra and other skeletal disturbances. Urinary calculi commonly develop, leading to renal colic and hematuria. The blood serum calcium varies from 12 to as high as 23 mg. per



FIG 14—Roentgenogram of bone lesions in the tibia and fibula, associated with hyperparathyroidism Note the definite rarefaction of the bones which is due to depletion of calcium and phosphorus. The fibula shows marked cystic destruction in its upper portion with expansion of the bone shell and without healing bone reaction The shaft of the tibia reveals a large cystic area with erosion of the cortex

100 cc., while the plasma phosphorus may be depressed as low as 1 or 2 mg. per 100 cc. of blood. The endocrine basis for the various changes seen in this disease have been well substantiated. Parathyroid adenomas are being demonstrated in increasing numbers of cases. In the differential diagnosis of osteitis

fibrosa cystica generalisata, fibrous dysplasia, multiple myeloma, and metastatic carcinoma are to be considered. The roentgenograms reveal multiple cysts with or without diffuse rarefaction or bending deformities (Fig. 14). In those lesions which have been biopsied, the microscopic structure varies, depending on the activity of the disease. The aggressive phase of osteitis fibrosa is characterized by tissue typical of giant cell tumor, while in the chronic or less active state, the sections reveal tissue characteristic of the healing reaction about bone cysts.



FIG 15A — Roentgenogram of monostotic fibrous dysplasia in a boy of 18 years The lesion is noted in the metaphysis of the upper end of the femur producing an area of polycystic destruction traversed by delicate trabeculae of bone. The defect is eccentric in position with expansion of the shaft There is loss of cortical density. Note the pathologic fracture

The treatment is directed toward the underlying cause of the condition, i.e., the hyperplasia or adenoma in parathyroid glands. After the diagnosis is established, the parathyroid glands should be explored. It is to be remembered that some parathyroid adenomas have been found within the upper thoracic cavity.

Fibrous Dysplasia There are two forms of fibrous dysplasia, the diffuse or polyostotic form, and the monostotic form.

In the diffuse or multiple form of fibrous dysplasia, the disease involves multiple bones on one side of the body. Occasionally there is a bilateral disturbance. Albright and his co-workers have emphasized the extraskeletal features of the disease, which include pigmentation of the skin and endocrine dysfunction in

girls in the form of sexual precocity and hyperthyroidism. These manifestations are not present in all cases. On roentgenographic examination, the bones are bowed and rarefied, with thinning and expansion of the cortex. *Pathologic fractures occur* (Figs. 15A and 15B). The pathologic changes show the interior of the bone to be replaced by fibrous tissue of a gray or yellowish color which may contain islands of calcification, cartilage, ossified bone, or small cysts (Fig. 15C).

In monostotic fibrous dysplasia, the first evidence of the disease is usually a



years of age
d secondarily
ie cystic area
There is little tendency to healing bone reaction about the lesion.
(Case of Dr. Jessie Nicholson)

local swelling with an occasional tenderness or pain of a rheumatic character. Pathologic fracture may be the first sign of the disease. The lesion appears either *to grow slowly or to remain stationary. Cutaneous and endocrine abnormalities* are lacking. The flat as well as the long bones may be affected. The roentgenogram shows, in the long bones, an area of radiolucency, sometimes traversed by delicate trabeculae of bone. These may be centrally placed or eccentrically located, especially in the metaphyseal area of the long bones.

Fibrous dysplasia is apparently a true d*ystrophy where the tendency to normal*

ossification is prevented by a fundamental local disturbance yet to be demonstrated.

It is usually recognized at the beginning of the second decade, though most often comes under observation in the third decade. It appears to be a chronic disease persistent throughout life.

Surgical excision is justified in lesions that give rise to symptoms or interfere with functional activity. Resection or thorough curetting should be performed; incomplete removal leads to recrudescence of the process. Irradiation is without benefit.



Fig 15C.—Photograph of tissue removed from the lesion shown in Fig. 15B. Note the fairly well vascularized connective tissue with trabeculae of partly calcified, newly formed bone. Bone formation is most abundant at the periphery of the lesion. Occasionally areas of cartilage are seen in some of these lesions

Benign Giant Cell Tumor. This is an epiphyseal lesion which occurs after the age of 18 years. It is most frequent in the lower end of the femur, upper end of the tibia, and lower end of the radius. The duration of symptoms averages 14 months. The sequence of events is trauma, pain, tumor, and, occasionally, pathologic fracture. In the roentgenograms an early giant cell tumor shows a defect situated asymmetrically in an epiphysis, later in the disease extending to a more central position. The defect is surrounded by a bone shell which may be perforated. The lesion is progressive. Microscopically, the tumor is composed of large giant cells,

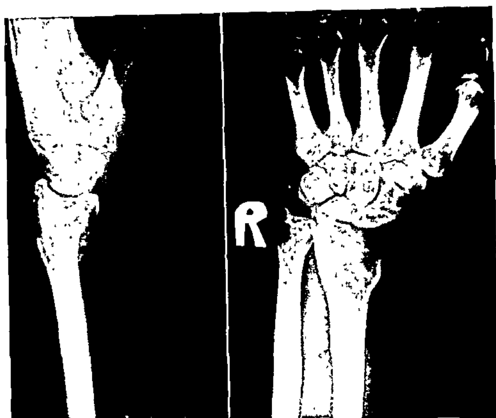


Fig. 16A.—Roentgenogram of a benign giant cell tumor of the lower end of the radius. Note the asymmetrical position of the expanded bone shell in the region of the epiphysis. Trabeculae within the cystic area are seen. The bone shell is perforated on the medial side. This lesion underwent malignant change 10 years later after repeated curettage and postoperative irradiation.

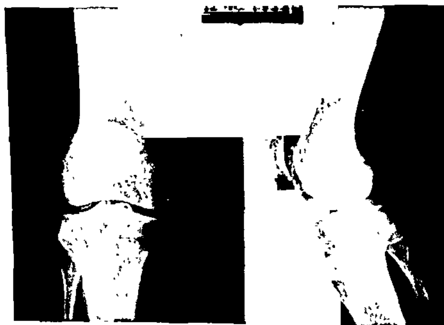


Fig. 16B—Roentgenogram of a benign giant cell tumor in the epiphyseal end of the lower femur. The bone shell is still intact. Trabeculae are present.

embedded in a mass of typical small spindle cells (Figs. 16A to 16D). There are a number of variants of giant cell tumor. Certain lesions of sesamoid bones, the jaws, and about the teeth are related pathologically to giant cell tumor.

Conservatism in the treatment of giant cell tumor has been in vogue since 1912. If one has to consider the economy of the time for convalescence, surgery is the procedure of choice. All lesions should be biopsied. In a primary case, not too advanced, curettage followed by cauterization is advocated, especially in the lower femur and the upper tibia. In advanced lesions of the ulna, fibula, or radius, resection should be used. *Recurrences following curettage may be troublesome*



Fig 16C—Roentgenogram of an early benign giant cell tumor in the upper end of the tibia. Note the subperiosteal position of the lesion in the epiphysis without periosteal reaction.

and call for further curettement or even resection where possible. An uncontrolled giant cell tumor is usually due to incomplete removal, perforation of the bone shell, or declining reaction of the bone cortex due to age. Many giant cell tumors are radiosensitive but the mechanism of response is not well understood. Opinion varies greatly on the efficacy of irradiation versus surgical intervention in benign giant cell tumor. It is well established that certain lesions irradiated alone or treated by surgery alone heal perfectly, but the combination of the two forms of therapy may give many unfortunate results. Treatment by irradiation is less favorable in the weight-bearing bones than in other locations. Many giant cell tumors *are inoperable because of their location or extent but may be successfully treated*

with roentgen therapy. Fractionated doses of *irradiation, given after sufficient intervals of time, are an important* factor in avoiding deformity and other complications. A small percentage (1 to 2 per cent) of giant cell *tumors undergo* malignant change. In nearly every case where *this is found prolonged* and ill-advised irradiation has been given. The microscopic differentiation between osteolytic sarcoma and benign giant cell tumor is difficult at times and adds to the number of cases in which sarcoma is discovered late in the disease.

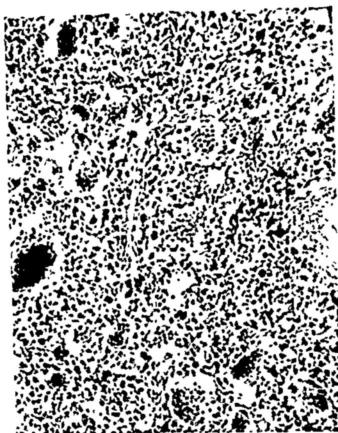


Fig 16D—Microphotograph of a benign giant cell tumor showing multinuclear giant cells embedded in a mass of small round and spindle cells. The giant cells average over 30 per field under low power with the number of nuclei varying in each cell from 50 to 100.

TUMORS OF NONOSSEOUS ORIGIN

Marrow and Haversian Systems

Ewing's Sarcoma or Endothelial Myeloma. This malignant tumor which arises *intracortically or subperiosteally* occurs in the first two decades of life; it involves the metaphysis primarily, most often affecting the long pipe bones, especially the tibia and femur. Other bones involved include the ilium, scapula, clavicle, vertebrae, skull, *and bones of the hands* and feet. The disease never involves the epiphysis primarily. It shows the usual symptoms of pain and tumor followed by dysfunction. In the roentgenogram a widening of the shaft, with increase in cortical structure and onionskin *periosteal reaction, is* an early finding, followed later by varying degrees of bone destruction (Fig. 17A). Microscopically, the

tumor is composed of small round cells, with dense nuclei and scanty cytoplasm, simulating a lymphosarcoma (Fig. 17B). Constitutional reaction is reflected in temperature elevation and leukocytosis. Marked weight loss is a late feature of the disease.

Irradiation provides a good therapeutic test and the best available palliative therapy. Irradiation alone, however, is not sufficient to control Ewing's sarcoma in the majority of cases. A review of the literature leads to the conclusion that combined preoperative irradiation (Coutard method) in full therapeutic dosage, followed by amputation or radical resection, gives the best results (19 per cent five year survivals). The average five year survival rate in all forms of treatment



Fig. 17A.—Roentgenogram of Ewing's sarcoma showing characteristic onionskin appearance of the periosteal reaction and the diffuse involvement of the shaft of the humerus Note the thickened cortex which is seen in the earlier phases of bone involvement.

is 10 per cent. Irradiation alone has been responsible for five year survivals in 2 of our cases, one, a patient in whom the tibia was explored, curetted, and then given intensive roentgen therapy. Another patient clinically showed Ewing's sarcoma in the femur, refused operation, and received intensive roentgen ray treatment. The leg was amputated six years later because of radiation fibrosis. No residual tumor was found Resection of the clavicle and a portion of the scapula in successive cases, followed by intensive roentgen therapy, has yielded five year survivals.

Reticulum Cell Sarcoma of Bone. This is a subvariety of Ewing's tumor frequently seen after the age of 35 years, similar to the radiologic and microscopic picture of typical Ewing's sarcoma (Fig. 17C). The prognosis is said to be much

better in this group. There is some doubt among some investigators as to whether this tumor should be separated from Ewing's sarcoma.

Multiple Myeloma. As the name implies, this neoplasm produces extensive tumor involvement of the skeleton. The disease develops in multiple foci throughout the red marrow of adults. The ribs, spine, pelvis, femur, and skull are most frequently affected. The patients are usually in the sixth decade of life. Clinically, in addition to the rheumatic pain, skeletal deformities ultimately leading to changes in the central nervous system, thorax, and lungs are manifested. Bence



FIG 17B.—A photomicrograph showing the characteristic cell of Ewing's sarcoma with indistinct cytoplasm and round and oval nuclei. Fibrous septa are seen which at times give the tumor an alveolar arrangement.

Jones bodies appear in the urine in about 65 per cent of the cases. The plasma proteins may be markedly increased. In the roentgenogram, the bones show multiple punched-out areas varying from 1 to 5 cm or more in diameter. In the skull the areas of rarefaction appear between the inner and outer tables of the bone (Fig. 18A). Pathologic fracture occurs in 62 per cent of the cases, a rib being the most frequent site of fracture. Microscopically, the tumors are composed of plasma-like cells with eccentric nuclei containing spoke-like arrangements of the chromatin. Fusiform cells and binucleate plasma cells are also present. There is a scant amount of intercellular substance (Fig. 18B). A sternal marrow punc-

ture is a valuable diagnostic procedure for obtaining marrow tissue which will reveal characteristic plasma cells when the tumor is present (Fig. 18C).

Prognosis is uniformly unfavorable though some cases have lived as long as seven years after the diagnosis was made. The prognosis seems to be little influenced by treatment, although roentgen or radium therapy may bring about remissions. The average duration of life is three years after coming under observation. Among palliative measures other than irradiation is the administration of stilbamidine and pentamidine in conjunction with a diet low in animal protein. More recently, urethane given in protracted dosages has shown promise in inhibit-



Fig. 17C.—Roentgenogram of Ewing's tumor in an adult, revealing rarefaction and destruction of the cortex. Histologically, this lesion is a subvariety of Ewing's tumor frequently called reticulum cell sarcoma of the bone.

ing the progress of the disease. In a few patients radioactive phosphorus has relieved pain and retarded the disease for a limited time. Deep roentgen therapy is the most valuable form of treatment in bringing about symptomatic improvement.

Some Diseases of the Bone Marrow and Lymphoid Tissue with Osseous Changes. Hodgkin's Granuloma: The bone marrow is more frequently involved in Hodgkin's granuloma than is usually supposed, involvement up to 40 per cent being reported in cases coming to necropsy. Since the advent of roentgen therapy, groups of cases are available in which the earlier symptoms referable to the bones



FIG. 18A.—Roentgenogram showing typical punched-out areas of bone destruction in a case of multiple myeloma. There is no increase in the width of the tables of the skull. Other bones show similar punched-out areas varying from a few millimeters to 5 cm. in diameter.

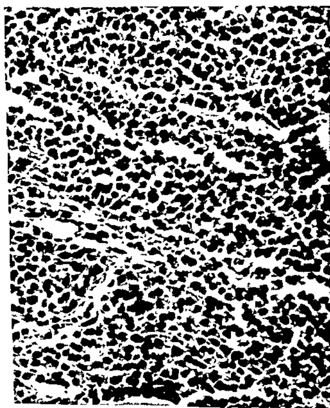


FIG. 18B.—Microphotograph of a typical plasma cell type of myeloma. Binucleate giant cells may be seen. A high powered photomicrograph will show spoke-like arrangement of the chromatin within the nuclei.

may be compared with the roentgenogram for the first evidence of bone changes. The duration of Hodgkin's granuloma before and after definite invasion of bone is quite variable. Some patients are living with bone changes which have existed from three to four years. Superimposed on the systemic manifestations of the disease may be the changes brought about by bone destruction, such as pain, rigidity of the spine, and localized tenderness of the affected bone. The blood picture is quite variable, ranging from leukopenia to marked leukocytosis. A marked secondary anemia is present in some cases. The bone changes as seen by



Fig 18C.—High powered photomicrograph of a smear obtained from a sternal marrow puncture Note the characteristic plasma-like cells with a binucleated giant cell. Such a smear is a valuable diagnostic finding.

roentgenograms are either osteoclastic or osteoplastic. Roentgenograms of the skull usually show a predominant osteolytic reaction Rarefied areas in the bone are surrounded by varying degrees of increased density, representing healing bone activity. Biopsies from the bone lesions show varying stages of disease activity (Fig 19). While irradiation is still the treatment of choice, other forms of palliative therapy include nitrogen mustards, nickel octyl-phthallate, and radioactive phosphorus. The disease has been found to be uniformly fatal following bone involvement.

Lymphosarcoma: Bone involvement in lymphosarcoma is rare. In a large series

of cases studied, only 10 per cent were ultimately found to have involvement of the bone. Pain is an early symptom with a variable interval before definite roentgenographic changes could be seen. Most of the patients die before the third year of the disease. Demonstrable changes in the bone are noted from 20 days to one year prior to death. As in Hodgkin's granuloma, the systemic manifestations of the disease are superimposed on changes brought about by osseous involvement, such as localized pain, girdle pain, and symptoms of cord compression. Bones involved, as in Hodgkin's granuloma, are those containing red marrow. Roentgenographically, the lesions are either predominantly osteoplastic or osteolytic.



As the disease progresses, the entire bone is frequently involved (Fig 20A). The osteolytic changes are seen more frequently. The microscopic picture is characteristic of lymphosarcoma, a diffuse growth of lymphoid cells lying in reticular tissue (Fig. 20B). The treatment of lymphosarcoma is by irradiation and other palliative forms of therapy such as are used in Hodgkin's granuloma.

Chloroma and the Leukemias: Chloroma is a rare form of bone disease usually involving the skull, vertebrae, spine, sternum, pelvis, and long bones and associated with leukemia. There is a special tendency to infiltration of muscles and tendinous attachments near the affected bones. The disease usually occurs about

the time of puberty. It frequently involves the orbital structures, causing an exophthalmos. Enlargement of the lymph nodes, liver, and spleen is also found. Roentgen *examination reveals areas of bone destruction or areas of rarefaction.* Occasionally a periosteal reaction may be seen. The tumor tissue is definitely green in color, and on section shows an increase in fibrous stroma with a crowding of large, atypical monocytes everywhere. The disease is usually a form of myeloid leukemia in which bone manifestations are a prominent feature. The process is radiosensitive and roentgen therapy is recommended for palliation.

Bone changes associated with lymphatic or myeloid leukemia are relatively rare. They frequently appear late in the disease. In lymphoid leukemia bone changes are found more often than in the myelogenous variety. Apparently there is no



Fig 20A —Roentgenogram of the pelvis, showing erosion of the pubis and ischium produced by lymphosarcoma Periosteal reaction is visible at the symphysis

correlation between the early development of changes in the bone and the duration of life after such changes appear When bone manifestations are prominent and appear early, the diagnosis is apt to be confused with multiple myeloma or chloroma. The total white count usually remains low in these cases, varying from 5000 to 12,000 cells per cubic centimeter In lymphoid leukemia the long bones are more frequently affected than are the pelvis, skull, or vertebrae. The roentgenogram reveals rarefaction in the long bones with a slight periosteal reaction Occasionally the changes resemble an early Ewing's sarcoma. In the skull osteoporotic changes, diffusely scattered, with neighboring periosteal elevation or thinning, is the characteristic picture Microscopically the disease resembles lymphosarcoma or Ewing's sarcoma of bone. The involvement of other organs, however, is diagnostic when considered with findings in the blood. Fractionated

doses of roentgen rays over the affected bones and lymph nodes or radioactive phosphorus is excellent palliative therapy.

Granulomatous Lesions of Bone. This group of bone lesions is often associated with disturbances in lipoid metabolism. Organs connected with the reticulo-endothelial system reveal a variety of changes.

There appears to be a close *relationship* between Letterer-Siwe disease, Hand-Schuller-Christian disease and eosinophilic granuloma. Further, it seems logical to assume that these diseases represent gradations of disturbance in lipoid metabolism in the reticulo-endothelial system.

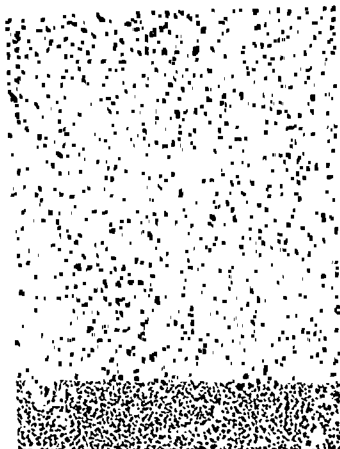


Fig. 20B.—Photomicrograph of lymphosarcoma which involved the bone as shown in Fig 20A. Note the diffuse growth of lymphoid cells lying in reticular tissue An occasional large reticulum cell is seen

Letterer-Siwe Disease: This nonlipoid histiocytosis is a rapidly fatal disease of infancy, seldom seen after the age of two years. The clinical features are fever, skin rash, purpura, and a rapidly developing and severe anemia. There is marked proliferation of cells in the reticulo-endothelial system, namely, the spleen, lymph nodes, and also lymphoid tissue in the skin. Bone lesions are encountered, identical with those of Hand-Schuller-Christian disease. Patients seen at this age invariably die.

Hand-Schuller-Christian Disease. The disease usually makes its *appearance in* late infancy and is rarely seen after childhood. The clinical manifestations are

variable. Exophthalmos, diabetes insipidus, pigmentation of the skin, and splenomegaly may be observed. Bone changes are a constant finding and roentgenographically appear as large, rarefied defects, clearly demarcated in the skull and in other flat bones. (Figs 21A and 21B). Diffuse cystic areas may also be seen in the long bones with thinning of the cortex. There is no periosteal reaction. The blood picture may show a severe anemia. Transfusions are frequently indicated during the period of active roentgen therapy. Small divided doses are best tolerated Many of these patients survive for an indefinite time with relative quiescence of the disease as they grow older.

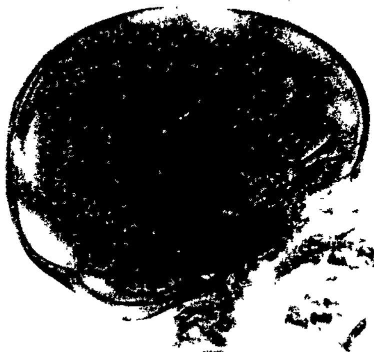


FIG 21A —Roentgenogram of the skull of a child with Hand-Schuller-Christian disease Note the large osteolytic defect in the posterior parietal and occipital regions Multiple foci of destruction are usually present There is no reaction in the neighboring periosteum.

Eosinophilic Granuloma· Eosinophilic granuloma occurs in children and young adults It is a relatively benign lesion localized in the skeleton. It frequently appears as a single lesion arising in the medullary cavity, though often it may appear in multiple bones A complete skeletal survey in all patients will probably reveal that it is a multiple lesion of the bones in most of the cases. The symptoms are unreliable, though pain, swelling, and dysfunction are frequently observed. A mild leukocytosis and mild eosinophilia are usually present. Radiologically the lesions in the bones are central. Osteolytic and irregular defects are observed quite well circumscribed or punched out. The cortex may be expanded or perforated. Histologically the lesions show sheets of eosinophils with varying degrees of fibrosis and histiocytes interspersed through the lesion. Surgical excision or curettage promotes healing. Mild roentgen therapy also will control the disease. Spontaneous healing is rare.



Fig. 21B.—Photomicrograph of Christian's disease shown in Fig. 21A. Many large macrophages are noted, some with foamy cytoplasm intermingled with eosinophils and lymphocytes.

Metastatic Deposits

Metastatic Carcinoma. A large group of bone tumors consists of metastases arising from carcinoma and sarcoma primary in other organs. About half of the lesions may occur as a single focus in the end of the long bones, producing a central area of bone destruction, while the other half may involve the skeleton diffusely, producing either osteolytic or osteoplastic changes. The primary source of the tumor varies. The most frequent sites of the primary growths are: breast, kidney, prostate, thyroid, the gastro-intestinal tract, and the female genital tract. A solitary focus of destruction in a single bone is often produced by metastatic tumors of the kidney, thyroid, lung, bladder, and malignant mole. These solitary lesions are most often seen in the spine, the upper end of the humerus or femur, and, occasionally, the skull. Metastatic cancers of the breast or prostate usually produce multiple involvement of the pelvis, spine, skull, and upper end of the femur or humerus. With mammary carcinoma a central area of bone destruction may be seen in the roentgenogram which subsequently shows rapid destruction of the cortex from within the medullary cavity (Fig. 22). There is little or no bone expansion. Multiple lesions appear as mottling or punched out areas. These changes are central in location. In carcinoma of the prostate, osteoblastic changes may be seen with increased bone density at times suggestive of Paget's disease

riable. Exophthalmos, diabetes insipidus, pigmentation of the skin, and sple-megaly may be observed. Bone changes are a constant finding and roentgeno-aphically appear as large, rarefied defects, clearly demarcated in the skull and other flat bones. (Figs. 21A and 21B). Diffuse cystic areas may also be seen in e long bones with thinning of the cortex. There is no periosteal reaction. The ood picture may show a severe anemia. Transfusions are frequently indicated iring the period of active roentgen therapy. Small divided doses are best lerated. Many of these patients survive for an indefinite time with relative iiescence of the disease as they grow older.



; 21A.—Roentgenogram of the skull of a child with Hand-Schuller-Christian disease Note ; large osteolytic defect in the posterior parietal and occipital regions. Multiple foci of destruction are usually present There is no reaction in the neighboring periosteum.

Eosinophilic Granuloma. Eosinophilic granuloma occurs in children and young lults. It is a relatively benign lesion localized in the skeleton. It frequently ipears as a single lesion arising in the medullary cavity, though often it may ipear in multiple bones A complete skeletal survey in all patients will probably veal that it is a multiple lesion of the bones in most of the cases. The symptoms e unreliable, though pain, swelling, and dysfunction are frequently observed. mild leukocytosis and mild eosinophilia are usually present. Radiologically the sions in the bones are central. Osteolytic and irregular defects are observed iite well circumscribed or punched out. The cortex may be expanded or per-rated. Histologically the lesions show sheets of eosinophils with varying degrees fibrosis and histiocytes interspersed through the lesion. Surgical excision or irettage promotes healing. Mild roentgen therapy also will control the disease. iontaneous healing is rare.

swelling, and dysfunction—is about one year. The lower femur and tibia are favorite sites for involvement. Rarely the upper extremity, skull, ribs, and pelvis may be affected. Microscopically, the spindle cell varies from the more aggressive oat cell type to the large fusiform spindle cell, with transition cell forms. There is usually no bone or cartilage seen in the fibrosarcomas. A definite percentage of the fascial sheath tumors are not sarcomas but cellular fibromas. This accounts in part for the unusual number of cures of so-called "fibrosarcomas."



Fig. 23.—The osteoplastic nature of bony metastases from carcinoma of the prostate is depicted in this roentgenogram. Note the sclerotic changes in the lumbar vertebrae, in the wings of the sacrum, and in the ilia Osteolytic changes are frequently seen in association with the dominant sclerosing reaction.

These tumors are not highly radiosensitive. The cell differentiation is all-important in this group. There is some evidence that irradiation inhibits tumor growth for a time, producing a slow sclerosing reaction in the fibro-spindle-cell type of lesion. Cases with the fibro-spindle cell variety of tumor may survive five years or longer, no matter how inadequate the treatment The majority of cures result from amputation or radical resection. The undifferentiated oat cell type of fibrosarcoma is extremely aggressive and neither radiation, nor local excision offers a permanent cure.

The neurogenic sarcomas (Fig. 24A), invading bone clinically, bear a close roentgenographic resemblance to the lesions of the fibro-spindle-cell series just discussed, though more pronounced destruction of bone is noted. As in the fibro-spindle cell tumors, there is a gradual transition among the neural tumors from the benign neurofibromas to the most malignant form of neurogenic sarcoma. The

(Fig. 23). Biopsy from such an area reveals that there is much reactive bone about the tumor infiltration This reaction of bone in prostatic carcinoma is quite the reverse of that seen in other metastatic lesions

Roentgen therapy offers varying degrees of palliation in bone metastases. The disappointing results have stimulated investigators to seek other therapeutic measures. Testerone and castration have proved beneficial in bone metastases from carcinoma of the female breast. Estrogenic therapy and orchiectomy have given effective palliation to patients suffering with bone metastases from prostatic



Fig. 22.—Mammary carcinoma involving the pelvis and upper ends of the femora Note the multiple punched-out areas in the upper femora and in the ischium and pubic bones There is evidence of sclerosis about the punched-out areas in the upper femora. This is rare in mammary carcinoma

cancer and male breast cancer. The heavy metals, particularly nickel octylphthallate, have been of some value in relieving pain and temporarily suppressing the extension of the disease.

Osseous Invasion by Inclusion or Invasion of Miscellaneous Tumors. Fibrosarcoma may arise either from the outer layers of the periosteum or in the adjacent soft parts The tumor occasionally invades the neighboring skeleton, giving rise to changes which are principally due to secondary bone involvement. Such bone involvement is infrequent (1 5 per cent of all neoplasms involving bone). The peak incidence is beyond the age of 30 years and parallels more closely the carcinomas among adults. The average duration of symptoms—consisting of pain,

swelling, and dysfunction—is about one year. The lower femur and tibia are favorite sites for involvement. Rarely the upper extremity, skull, ribs, and pelvis may be affected. Microscopically, the spindle cell varies from the more aggressive oat cell type to the large fusiform spindle cell, with transition cell forms. There is usually no bone or cartilage seen in the fibrosarcomas. A definite percentage of the fascial sheath tumors are not sarcomas but cellular fibromas. This accounts in part for the unusual number of cures of so-called "fibrosarcomas."



FIG. 23.—The osteoplastic nature of bony metastases from carcinoma of the prostate is depicted in this roentgenogram. Note the sclerotic changes in the lumbar vertebrae, in the wings of the sacrum, and in the ilia. Osteolytic changes are frequently seen in association with the dominant sclerosing reaction.

These tumors are not highly radiosensitive. The cell differentiation is all-important in this group. There is some evidence that irradiation inhibits tumor growth for a time, producing a slow sclerosing reaction in the fibro-spindle-cell type of lesion. Cases with the fibro-spindle cell variety of tumor may survive five years or longer, no matter how inadequate the treatment. The majority of cures result from amputation or radical resection. The undifferentiated oat cell type of fibrosarcoma is extremely aggressive and neither radiation, nor local excision offers a permanent cure.

The *neurogenic sarcomas* (*Fig. 24A*), invading bone clinically, bear a close roentgenographic resemblance to the lesions of the fibro-spindle-cell series just discussed, though more pronounced destruction of bone is noted. As in the fibro-spindle cell tumors, there is a gradual transition among the neural tumors from the benign neurofibromas to the most malignant form of neurogenic sarcoma. The

more malignant and cellular forms predominate where bones are involved. They are differentiated microscopically by the myxomatous structure intermingled with the fibrous tissue. Nuclei are longer and deeper staining Many tumor giant cells may be seen (Fig 24B).

Neurogenic sarcomas as a group are highly radioresistant tumors. Interstitial irradiation by buried radon implants has been almost uniformly disappointing. A certain number of cases has shown some regression by external irradiation alone. It may be stated, however, that clinical cures in neurogenic sarcoma are obtained by early amputation, and even with this radical form of treatment, permanent cures are not numerous.



FIG 24A —Gross specimen of a neurogenic sarcoma of the peroneal nerve invading the tibia in a girl 15 years of age, living and well 12 years after amputation

Angioma of the bone is considered rare. This growth appears between the ages of four and 40 years but is most frequent among young adults. Such tumors have been found in the humerus, ulna, radius, femur, os calcis, skull, and vertebrae. The roentgenographic picture is one closely resembling giant cell tumor or polycystic disease of the bone (Figs 25A and 25B) In addition, however, one may see isolated cysts beyond the main point of destruction. The trabeculae traversing the cystic cavities vary in density, more so than in giant cell tumor. These lesions at exploration show cystic destruction, with or without vascular tissue beneath a

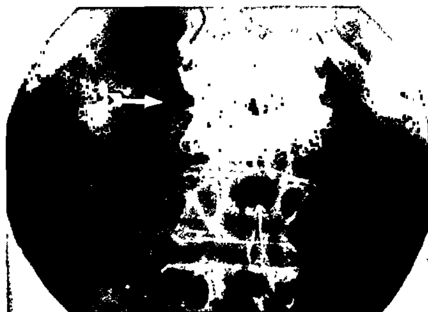
thin wall of cortical bone. The cysts contain fluid as a rule. The vascular tissue obtained is characteristic of angiomatous tissue elsewhere. On reviewing the literature, one gains the impression that the majority of the angiomas of bone are of the cavernous type. In our cases, many showed the capillary type of angioma and two with proliferative changes suggested malignant change.

., but not always, benign. They show varying degree ... ie younger the patient, the more effective the irradiation. This factor is also present in angiomas found in other parts of the body. Isolated examples may be pointed out as having been cured by roentgen therapy alone or by *surgical intervention.*



FIG 24B —Photomicrograph of tumor tissue removed from the lesion depicted in Fig. 24A Note the elongated spindle cells with many large giant cells and the tendency for the cells to line up in parallel rows. Such tumors microscopically may be graded according to cellularity

Occasionally lymphangioma is noted, involving one or more bones with changes much like those seen in angioma. In one case marked resorption of bone structure was noted in the ischium and ilium (Figs. 26A and 26B). The surrounding soft parts show invasion by the lymphangiomatous process. Microscopically lymphangiomatous channels were noted, some of which were quite dilated (Fig. 26C). The lymphangiomatous tissue was associated with accumulations of lymphocytes and lymphoid tissue. Bone surrounding resorption areas revealed little evidence of osteoblastic activity. The treatment is largely limited to roentgen therapy.



A

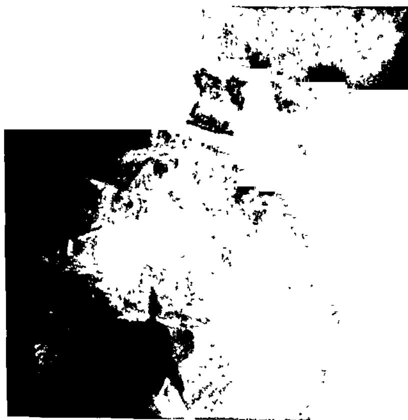


B

Fig. 25.—Roentgenograms of angioma involving the first lumbar vertebra. The rarefaction has a fine honeycombed appearance and delicate radiating spicules of new bone are seen



A



B

... a lymphangioma involving the femur, pelvis, ... ic destruction at the upper end of the femur. ... in the lateral view of the sacrum and in the fourth and fifth lumbar vertebrae Soft part tissues were also invaded

(Case of Dr. W H. Bickel, by Courtesy of the Mayo Clinic)

Chordoma is a rare malignant neoplasm found near the spheno-occipital or sacrococcygeal regions, thought to arise from remnants of the notochord Rarely these tumors have been found at various levels of the spinal column. Young adults and children are usually the age groups affected by the disease. The symptoms vary with the location Intracranial symptoms or symptoms from spinal cord and nerve involvement may be observed. A tumor in the cervical region may produce pharyngeal symptoms. The tumor is of slow growth but kills by invasion of vital structures Twenty-seven per cent of the growths are said to metastasize. The



FIG 26C—Microphotograph of lymphangiomatous tissue obtained from the lesion shown in Fig 26A Note the lymphangiomatous spaces invading muscle and areolar tissue lined by endothelium with accumulations of lymphoid cells in the tissues surrounding the lymphangiomatous spaces

roentgenogram usually shows destruction of bone associated with a soft part shadow The microscopic picture is variable Solid cords of polyhedral and globular cells, in some instances becoming more vacuolated and having a homogeneous intercellular mucinous matrix resembling hyaline cartilage, are seen. Great difficulty is experienced in differentiating them from atypical chondromas and mucoid carcinoma arising in the gastro-intestinal tract.

Irradiation has little effect on chordomas Surgical excision is the treatment of choice, but recurrence is the rule

Myosarcoma and liposarcoma are occasionally found invading bone and must be considered in the differential diagnosis of a variety of conditions under which neoplastic invasion of bone may occur.

REFERENCES

Albright, F., et al.: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and Endocrine Dysfunction with Precocious Puberty in Females, Report of 5 Cases. *New England J. Med.*, 216:727, 1937.

Chambers, T. R.. Myositis Ossificans, Study of Another Unusual Case. *Arch. Surg.*, 16.755, 1928.

Coley, B. L.: *Neoplasms of Bone and Related Conditions: Their Etiology, Pathogenesis, Diagnosis and Treatment.* New York: P. B. Hoeber, 1949.

Coley, B. L., and Coley, W. B.: Primary Malignant Tumors of Long Bones, End-results in 170 Operable Cases. *Arch. Surg.*, 14:63, 1927.

Coley, B. L., and Coley, W. B.: Primary Malignant Tumors of Long Bones; End-results in 170 Operable Cases, Including Small Group of Malignant Central Sarcoma. *Arch. Surg.*, 13 779, 1926

Copeland, M. M.. Bone Tumors with Reference to Their Treatment. *Surgery, 11* 436, 1942.

Copeland, M. M.: Skeletal Metastases Arising from Carcinoma and from Sarcoma. *Arch. Surg*, 23:581, 1931.

Copeland, M. M., and Geschickter, C. F.: Nature of Ewing's Tumors. *Arch Surg.*, 20:421, 1930.

Copeland, M M., Geschickter, C. F., and Bloodgood, J C.: Ewing's Sarcoma, Small Round-cell Sarcoma of Bone. *Arch. Surg*, 20.246, 1930.

Craver, L F., and Copeland, M. M.: Changes of Bones in the Leukemias. *Arch. Surg.*, 30.639, 1935.

Craver, L. F, and Copeland, M. M.: Changes in Bone in Hodgkin's Granuloma. *Arch. Surg.*, 28:1062, 1934.

Craver, L. F, and Copeland, M. M.: Lymphosarcoma in Bone. *Arch. Surg.*, 28:809, 1934.

Ehrenfried, A.: Hereditary Deforming Chondrodysplasia, Multiple Cartilaginous Exostoses, a Review of the American Literature and Report of 12 Cases. J.A M.A, 68.502, 1917.

Geschickter, C F.. Tumors of Muscle. *Am. J Cancer*, 22.378, 1934.

Geschickter, C. F. Osteogenic Sarcoma. *Arch. Surg*, 24:602; 798, 1932.

Geschickter, C. F., and Copeland, M. M.: *Tumors of the Bone.* Philadelphia: J. B Lippincott Company, 1949.

Geschickter, C. F., and Copeland, M. M.: *Tumors of the Bone,* (with Forewords by Dean Lewis and Joseph C. Bloodgood), New York: Am. J. Cancer, 1931.

Geschickter, C. F., and Copeland, M M.: Tumors of the Bone. *Internat. S. Digest*, 10.323, 1930

Geschickter, C. F., and Copeland, M. M Multiple Myeloma. *Arch. Surg.*, 16.807, 1928

Geschickter, C. F., and Maseritz, I. H.: Primary Hemangioma Involving Bones of Extremities J Bone & Joint Surg., 20·888, 1938.

Higinbotham, N. L.: The Surgical Treatment of Giant-cell Tumors of Bone and Allied diseases, in *Treatment of Cancer and Allied Diseases.* New York P. B. Hoeber, 1940, vol. 3, p. 2375

Jaffe, H. L.: Hereditary Multiple Exostosis *Arch Path*, 36 335, 1943.

Jaffe, H. L., and Lichtenstein, L.: Benign Chondroblastoma of Bone, Reinterpretation of So-called Calcifying of Chondromatous Giant Cell Tumor. *Am. J. Path.*, *18:969*, 1942.

Kolodny, A.: Bone Sarcoma, Primary Malignant Tumors of Bone and Giant Cell Tumor Surg, *Gynec. & Obst.*, 44·1, 1927.

Kuzma, J. F, and King, J M.: Dyschondroplasia with Hemangiomatosis (Maffucci's Syndrome) and Teratoid Tumor of the Ovary *Arch. Path*, 46:74, 1948.

Mabrey, R E: Chordoma, Study of 150 Cases. *Am J. Cancer*, 25.501, 1935.

Rowland, R. S Christian's Syndrome and Lipoid Cell Hyperplasias of Reticulo-endothelial System *Ann Int. Med.*, *2*:1277, 1929

Rowland, R. S: Xanthomatosis and Reticulo-endothelial System, Correlation of Unidentified Group of Cases Described as Defects in Membranous Bones. Exophthalmos and Diabetes Insipidus (Christian's Syndrome). *Arch. Int. Med*, *42*:611, 1928.

Schlumberger, H G: Fibrous Dysplasia of Single Bones (Monostotic Fibrous Dysplasia). *Mil Surgeon*, 99:504, 1946

Shelling, D. H, and Voshell, A F.: Xanthomatosis Generalisata Ossium; Report of Case Simulating Osteitis Fibrosa Cystica. *Arch. Int Med*, *55*:592, 1935.

Simmons, C C Bone Sarcoma, Factors Influencing Prognosis. *Surg, Gynec. & Obst*, *68* 67, 1939

Stewart, F. W.: Radiosensitivity of Tumors. *Arch. Surg*, *27*:979, 1933

Stewart, F. W, and Copeland, M. M.. Neurogenic Sarcoma. *Am. J. Cancer*, *15*:1235, 1931.

Internal Derangements of the Knee

EDWIN F. CAVE, M.D.

OF ALL THE joints of the body, the knee is the one most frequently subjected to trauma, and of the weight-bearing joints, it is, because of its anatomic structure, the least able to withstand injury. It must rely entirely upon muscular and ligamentous structures for its support, as contrasted to the hip and ankle which are rendered less vulnerable by their ball and socket, and mortice arrangements respectively.

ANATOMY

The supporting structures of the knee are anteriorly, the extensor apparatus and lateral expansions; laterally, the joint capsule, the external fibulofemoral ligament, the popliteus tendon, the iliotibial band, and the biceps tendon; posteriorly, the two heads of the gastrocnemius, the biceps tendon, the posterior capsule, the popliteus muscle, and the inner hamstring tendons; mesially, the inner hamstring tendons, the mesial joint capsule, the tibiofemoral ligament, the gracilis and sartorius tendons, and the quadriceps expansion. Internally, the joint is firmly supported by the anterior and posterior cruciate ligaments (Figs. 1 and 2).

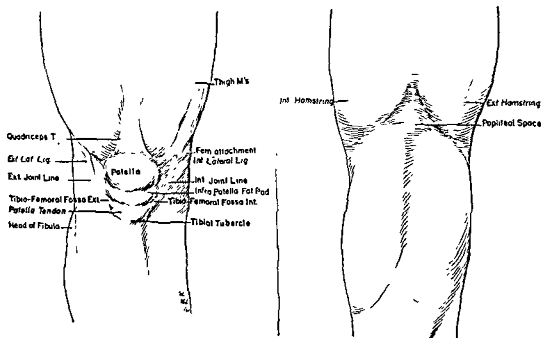


FIG 1.—Surface anatomy and important points to palpate in examination of the knee.

Fig 2.—Lateral, mesial, and posterior aspects of the knee joint and its supporting structures.

BONY ARCHITECTURE

The femoral condyles are curved in a convex manner to fit into the concave compartments of the tibial head. The maximum curve of the femoral condyles occurs slightly posterior to the midline when viewed laterally, so that the greatest compression between the femoral and tibial condyles occurs at these points, as frequently happens in semilunar cartilage injury. The lateral condyle is smaller than the mesial one, and this deficiency is at times so marked that lateral displacement of the patella may occur. The patella, the largest sesamoid bone and an important part of the extensor apparatus, rides in the groove between the femoral condyles during flexion and extension of the joint, creating a constant source of friction, resulting in the earliest hypertrophic changes in the joint as age progresses. The semilunar cartilages are rudimentary affairs and represent remains of true cartilaginous cushions found in the lower vertebrates. In man, it is doubtful that they serve any important function.

EXAMINATION OF THE KNEE

As in any physical examination, the knee must be examined in a routine and systematic manner (Fig. 3).

METHOD

The patient sits on an examining table with both lower extremities exposed, and knees relaxed in flexion at approximately 90°, with the feet hanging toward the floor. The examiner sits facing the patient.

Inspection. As the extremity is viewed, one looks for atrophy of the thigh muscles, swelling, or discoloration, obvious shortening or lengthening of the extremity, or gross deformity of any sort.

Palpation. The two knees are palpated at the same time, in flexion and later in extension The more painful parts should be examined last. The surface temperature is noted. The structures are palpated in a systematic manner, as follows: thigh muscles, *quadriceps tendon, patella, infrapatellar fat pad, patellar tendon, tibial* tubercle, internal tibiofemoral fossa, internal joint line, femoral and tibial attachments of the internal collateral ligament, hamstring tendons, popliteal space, external tibiofemoral fossa, external joint line, and fibulofemoral attachments of the external collateral ligament. If there is thickening of the synovia or increased fluid in the joint it should be noted.

These structures should be palpated in flexion as well as in extension, and in extension the patella should be tested for stability, for limitation of motion, or for crepitation between the patella and femur

The various regions can be palpated as the knee is brought from a flexed to an extended position and vice versa.

Motion. Flexion is measured in degrees from complete extension. Hyperextension should be recorded in degrees, and when there is loss of complete extension, this should be recorded in degrees of permanent flexion.

Stability. The stability of the knee should be tested at 90° flexion, and in complete extension. If in flexion the tibia can be displaced forward on the femur, it is

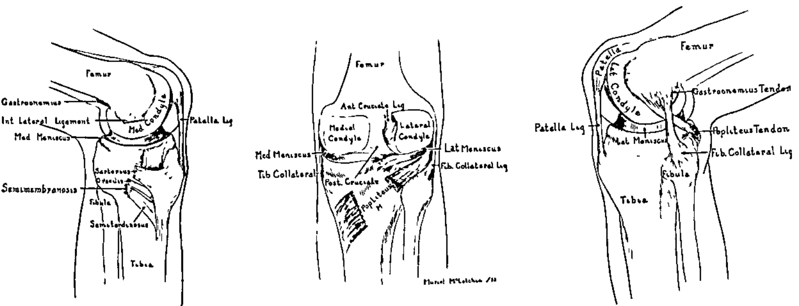


FIG 2.—Lateral, mesial, and posterior aspects of the knee joint and its supporting structures

BONY ARCHITECTURE

The femoral condyles are curved in a convex manner to fit into the concave compartments of the tibial head. The maximum curve of the femoral condyles occurs slightly posterior to the midline when viewed laterally, so that the greatest compression between the femoral and tibial condyles occurs at these points, as frequently happens in semilunar cartilage injury. The lateral condyle is smaller than the mesial one, and this deficiency is at times so marked that lateral displacement of the patella may occur. The patella, the largest sesamoid bone and an important part of the extensor apparatus, rides in the groove between the femoral condyles during flexion and extension of the joint, creating a constant source of friction, resulting in the earliest hypertrophic changes in the joint as age progresses The semilunar cartilages are rudimentary affairs and represent remains of true cartilaginous cushions found in the lower vertebrates. In man, it is doubtful that they serve any important function.

EXAMINATION OF THE KNEE

As in any physical examination, the knee must be examined in a routine and systematic manner (Fig. 3).

METHOD

The patient sits on an examining table with both lower extremities exposed, and knees relaxed in flexion at approximately 90°, with the feet hanging toward the floor The examiner sits facing the patient.

Inspection. As the extremity is viewed, one looks for atrophy of the thigh muscles, swelling, or discoloration, obvious shortening or lengthening of the extremity, or gross deformity of any sort.

Palpation The two knees are palpated at the same time, in flexion and later in extension. The more painful parts should be examined last. The surface temperature is noted The structures are palpated in a systematic manner, as follows: thigh muscles, quadriceps tendon, patella, infrapatellar fat pad, patellar tendon, tibial tubercle, internal tibiofemoral fossa, internal joint line, femoral and tibial attachments of the internal collateral ligament, hamstring tendons, popliteal space, external tibiofemoral fossa, external joint line, and fibulofemoral attachments of the external collateral ligament If there is thickening of the synovia or increased fluid in the joint it should be noted.

These structures should be palpated in flexion as well as in extension, and in extension the patella should be tested for stability, for limitation of motion, or for crepitation between the patella and femur.

The various regions can be palpated as the knee is brought from a flexed to an extended position and vice versa.

Motion. Flexion is measured in degrees from complete extension. Hyperextension should be recorded in degrees, and when there is loss of complete extension, this should be recorded in degrees of permanent flexion.

Stability. The stability of the knee should be tested at 90° flexion, and in complete extension If in flexion the tibia can be displaced forward on the femur, it is

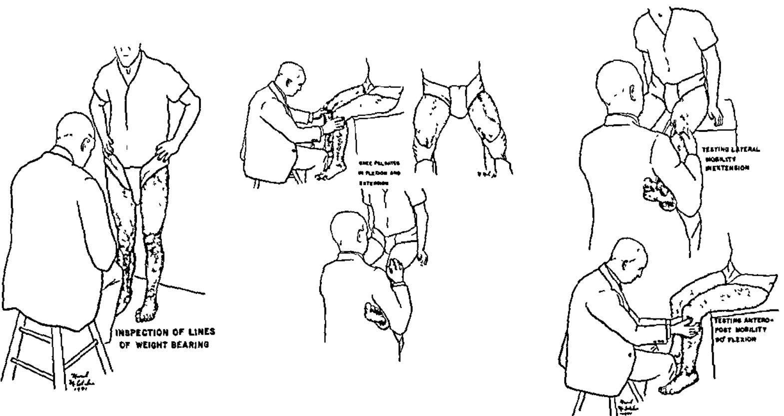


Fig 3.—Examination of the knee, inspection, palpation, and testing of motion

probable that there is injury to the anterior cruciate ligament. If it can be displaced backward, damage to the posterior cruciate should be suspected (Fig. 4).

Stance and Gait. As the patient stands and walks, the general contour of the lower extremity is noted, and the presence of pronation or other abnormality of the feet should be recorded.

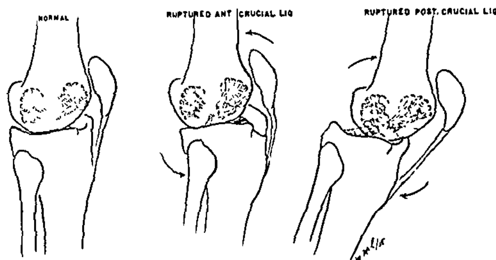


FIG 4 —Injury to cruciate ligaments. Damage to the anterior cruciate ligament allows forward displacement of the tibia on the femur. Injury to the posterior cruciate ligament permits anterior displacement of the femur on the tibia.

Measurements. For length, one should measure from the anterosuperior spines of the pelvis to the internal malleoli. Circumferential measurements 8 in. above, 4 in above, midpatella, and at mid-calf should be taken.

Examination of the joints above and below the knee should be carried out, namely, palpation and motions of the hip, ankle, and foot.

Reflexes. Knee jerks and ankle jerks must be tested.

TRAUMATIC CONDITIONS OF THE KNEE

The vast majority of injuries to the knee joint result from indirect trauma, as sustained from a twist or strain, rather than from a direct blow. The more common conditions resulting from this type of force are strain of the ligamentous support, particularly that of the internal lateral ligament, and injury to the semilunar cartilages Injuries to other external ligaments, the cruciate ligaments, or the articular surfaces occur less frequently.

INJURY TO THE INTERNAL COLLATERAL LIGAMENT

Strain of the internal lateral ligament is sustained by forced abduction of the leg on the thigh, or adduction of the knee (Fig. 5). This injury may result in partial or complete tear of the ligament, and the site of injury is almost always at its femoral attachment, and less often at the joint line. Characteristic symptoms ... lerness, ... lateral ligament. The diagnosis is based on an analysis of the type of injury sustained, on

objective symptoms, and on the absence of signs suggestive of internal semilunar cartilage injury, although there may be, at times, an associated injury to this structure. Roentgenograms are usually negative, save for increased density due to excessive joint fluid.

Treatment of internal lateral ligament strains should consist of rest in bed, if the injury is severe, with local applications of cold or heat for three or four days At the end of this time, the patient may be allowed up with the knee securely

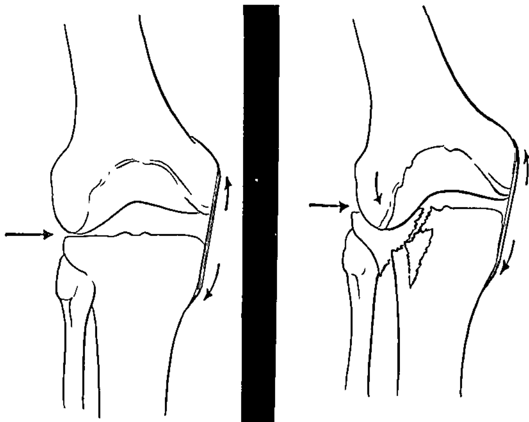


Fig 5.—Adduction injury to the knee There is sharp adduction of the knee which strains the internal lateral ligament If the force is sufficiently great, the lateral femoral condyle may be driven into the lateral tibial condyle and produce a compression fracture of the latter bone

strapped on the mesial and anterior aspects, and the strapping reinforced with an ace bandage. The vere tears If the tear is comp ata should be carried out If th semilunar cartilage at the same time, as its attachment to the internal lateral ligament will have been severed. Careful inspection of the remaining components should be carried out, and if there is a tear of the cruciate ligaments, they should be repaired.

Injury to the Cruciate Ligaments

A severe twisting injury is required to tear the cruciate ligaments. Injury to these ligaments is frequently associated with semilunar cartilage injury, and may be sustained by the same mechanism. The tear is more often incurred in the

anterior cruciate than the posterior, and usually occurs in approximately the central portion of the ligament, where nutrition is the poorest, and, consequently, healing does not occur. Not infrequently, the diagnosis will not be made because of failure to test stability of the knee in flexion at the time of injury. Often it is not until after months have elapsed that the patient becomes conscious of marked relaxation of the joint due to damage to one or both cruciate ligaments.

The diagnosis can be made only by testing stability of the knee at 90° flexion. If in this position the tibia can be displaced forward on the femur, a tear, or at *least relaxation of the anterior* cruciate must be suspected; if the tibia can be displaced backward abnormally, injury to the posterior cruciate ligament is probable (Fig. 4).

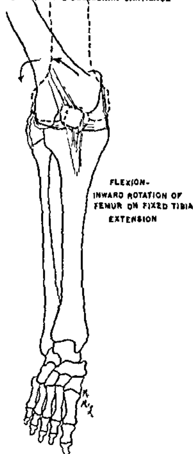
Treatment. The only real hope of restoring continuity of the torn cruciate ligament is to make the diagnosis within a few hours after injury, and perform an early operation to repair the tear. Usually a badly injured knee is too painful to examine adequately; therefore, in all severe knee injuries, examination of the joint under anesthesia is justified. If cruciate ligament injury is thought to be present, immediate operation through an adequate incision is indicated.

For the old cruciate ligament injury no satisfactory operation has as yet been uniformly successful. Thus far, any procedure which has been devised to stabilize the knee sufficiently limits motion too much and, therefore, is not justified. Consequently, the greatest hope for any knee with relaxation due to the cruciate ligament injury which has existed for months is to rebuild a strong quadriceps group of muscles with resistance exercises.

Semilunar Cartilage Injuries

Internal derangement of the knee, the most common cause of which is injury to the semilunar cartilages, is, in the vast majority of cases, sustained by indirect trauma (Fig. 6). The mechanism of injury to the semilunar cartilages is not always easy to determine, for it is frequently difficult for the patient to recall the exact way in which the trauma was sustained. The internal semilunar cartilage is usually injured by sudden external rotation of the thigh on the fixed leg, and abduction, and extension of the knee. This maneuver results in a tear of the anterior or mesial portion of the internal semilunar cartilage; it may split longitudinally, or be torn completely from its moorings. The internal lateral ligament at the attachment of the semilunar cartilage to its posterior part remains intact, but the attachment of the anterior horn, or weak coronary attachments, or both, are ruptured. The anterior portion of the cartilage is displaced, usually toward the interior of the joint. As its normal elasticity is interfered with, it is often impossible for it to retrace its steps, so that when extension is attempted, the displaced portion of the cartilage is pinched between the inner condyles of the femur and tibia. The posterior portion of the internal meniscus may be injured by forcible external rotation of the femur on the fixed tibia, combined with flexion. During this movement, the posterior part of the internal femoral condyle at the maximal curve sweeps across the posterior end of the meniscus, and if violent flexion occurs, the latter is liable to be split or detached. When rotation is more sudden and more severe, the internal meniscus may be torn from its attachment to the posterior fibers of the internal lateral ligament. If abduction of the leg is a marked feature

of the injury, both portions of the ligament may be severely stretched, or even ruptured, as in the case of internal lateral ligament tears, and the middle portion of the cartilage may slip into the interior of the joint when extension occurs When this happens, the cartilage may be split longitudinally, producing the typical "bucket-handle" type of lesion. This cannot uniformly be the cause of the "bucket-handle" type of split, however, since frequently at operation with this type of lesion, we find the outer portion firmly and apparently normally attached to the internal lateral ligament. The most common type of injury to the internal semi-



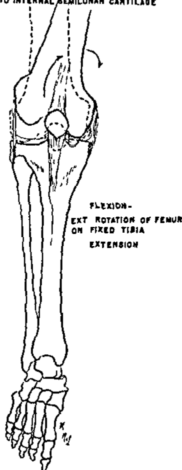


FIG 6 —Mechanism of injury to the semilunar cartilages.

lunar cartilage is the longitudinal split There have been no instances of transverse split of this structure in a series of 200 internal semilunar cartilages removed during a 10-year period. These 200 cases represent 68 per cent of the total cases in our series of internal derangement of the knee. Damage to the posterior portion of the internal semilunar cartilage may result from the mechanism as described above, but it may also come from compression of this part of the meniscus, such as that which occurs when the patient acutely flexes the knee, as in squatting. This kind of compression of the meniscus occurred in the following case.

A chauffeur, aged 30, was squatting to change an automobile tire. After assum-

ing the position for approximately 15 minutes, on arising and attempting to extend his knee, he found he was unable to do so. This difficulty persisted and was accompanied by pain and swelling in the joint, and one week later operation revealed a tear of the posterior third of the internal meniscus, with a free fragment attached by only a small pedicle and lying between the posterior portions of the tibial and femoral condyles. Removal of the entire meniscus gave complete relief.

In the case of injury to the external semilunar cartilage, of which there were only 19 cases, or 10 per cent of our cases, there is usually internal rotation of the femur on the fixed tibia, in the flexed position, plus adduction of the knee. Injury to, or displacement of, the posterior horn of the external meniscus, which is not an infrequent occurrence, is probably due to internal rotation of the femur on the fixed tibia, combined with severe flexion.



FIG 7.—(A) Multiple injuries to internal semilunar cartilage. (B) Split of the posterior third of the mesial meniscus with "loose body"

Symptoms and Signs. A few symptoms and signs are regarded as characteristic of semilunar cartilage injury. In a high percentage of a large series of cases, there were recurrent attacks of pain in 97 per cent, locking in 70 per cent, and swelling in 95 per cent. Once a semilunar cartilage is split longitudinally (Fig. 7), it does not heal and recurrences can be expected Characteristic findings on physical examination are atrophy of the quadriceps muscles, which occurred in 68 per cent of our cases, localized tenderness, and abnormal prominence of the meniscus at the joint line, which was found in 88 per cent, increased fluid, occurring in 50 per cent of the cases, and limited motion, particularly "fixed flexion," found in 63 per cent.

Roentgenographic Findings. In the uncomplicated meniscus injury cases, the roentgen rays will be "negative," unless by chance there is calcification of the injured portion of the semilunar cartilage. This is extremely rare, but should always be looked for, and a differential diagnosis made between a calcified cartilage and a "loose body" free in the knee joint. It has not been our practice to use pneumarthrograms. If the history is analyzed, and a careful physical examination

is made, we believe that the pneumarthrogram is unnecessary, and that at times it may be misleading.

In evaluating a patient with an injured meniscus, it is important to determine whether there are associated difficulties in the knee joint. In our series, 19 per cent of cases had injury to structures other than the meniscus, detected preoperatively or at operation These associated changes were as follows: osteochondritis of the femoral condyle, cruciate ligament injury, chondromalacia of the patella, traumatic arthritis in the knee joint, giant cell tumor of the knee joint capsule, calcification of the tip of the meniscus, and intra-articular ganglia.

Prognosis. If an injured meniscus not complicated by other joint changes is carefully removed with atraumatic technic, one can expect that the patient will be completely relieved and return to a normal existence. Postoperative rehabilitation of the extremity and the patient as a whole is essential. If this is not carried out, results will not be entirely satisfactory.

Treatment. Original Injury. When a patient presents himself with an acute injury to the knee, the first duties of the examining physician are to make an accurate diagnosis by taking a careful history of the mechanism of the injury, to do a careful local examination, and if possible to take roentgenograms before treatment is attempted If, in addition to pain and swelling of the knees, there is flexion deformity, probably the most important thing to accomplish is to gain and maintain complete extension of the knee as soon as possible. This can be accomplished by putting the patient to bed and applying local applications of cold or heat, and encouraging him gradually to straighten the knee; or by *gentle* manipulation, if necessary under anesthesia. Many flexion deformities will be due only to ligament strain and secondary hamstring muscle spasm, but some will be caused by a displaced semilunar cartilage. If the surgeon can be reasonably certain that the meniscus is damaged and displaced, the earlier the gentle manipulation is carried out, the better This should never be done with force. To do so will not only cause severe pain, but will also increase the damage to the cartilage. Many of these injured knees will straighten as soon as the patient is anesthetized, while others must be gently brought to extension without force. It is impossible to tell whether the injured meniscus has been replaced to its normal position by manipulation. But if extension can be gained, the surgeon should continue conservative treatment, consisting of adhesive strapping over the anterior aspects of the knee from mid-thigh to mid-leg, renewed at weekly intervals for three weeks. During this time, the patient is allowed up with crutches and must do quadriceps setting exercises At the end of three weeks, motion in flexion is allowed and the patient wears an elastic bandage to the knee until muscular support is strong Quadriceps exercises are continued until normal size and strength of the thigh muscles are restored. If the knee remains "locked" in flexion, it indicates that the displaced cartilage is interposed between the tibia and femur and operation is necessary.

Recurrent Meniscus Injuries. Unless the injury to the meniscus is a peripheral one, the damaged portion does not heal, because only at the periphery does the semilunar cartilage have a blood supply. Therefore, with the usual case, once the meniscus is split, it never heals and recurrent attacks of pain and "catching or locking" can be predicted, unless the patient uses his knee for restricted activity

If recurrent attacks do occur, operative removal of the damaged meniscus is indicated, not only to relieve symptoms, but also to prevent damage to the articular surfaces of the femur and tibia by the hypermobile fibrocartilage.

A satisfactory technic is as follows: The patient is instructed in quadriceps setting exercises prior to entering the hospital. He is hospitalized the day before the operation, and a careful preparation of the extremity from toes to groin is carried out by manicuring the toe nails, carefully shaving the entire leg and thigh, and gently scrubbing with soap, water, and alcohol. The extremity, including the foot, should be covered with one layer of sterile stockinette or towel. Anesthesia may be general or spinal. The method of preparing the skin and draping the leg on the operating table is a matter of choice of the individual surgeon. The operation is done under a pneumatic tourniquet which is inflated after the leg has been elevated for five minutes. If the surgeon is reasonably certain that the injury is confined to the semilunar cartilage and is in the anterior or mesial portion, he is justified in using one of the restricted anterior incisions (Fisher; Jones). If the lesion appears to be in the posterior portion, the "combined" incision is recommended, and if there is doubt as to whether the disability necessitating surgery is confined to the meniscus, or if there is evidence of associated lesions, one should then employ the parapatellar approach, through which the joint can be explored.

Rehabilitation The day after operation, quadriceps setting exercises are continued and are done at stated intervals during the day. As the patient is able to lift the leg from the bed with the knee straight, he is allowed up on crutches, and exercises in extension are continued. It is unnecessary to exercise the knee in flexion. Crutches are usually discarded at the end of a week or 10 days, the stitches are removed, and vigorous exercises are undertaken. For these, the patient sits with his leg over the side of a table with a weight of 2 to 3 pounds secured to the foot, and brings the knee from flexion to an extended position an increasing number of times, in order to rebuild the quadriceps muscles. The technic of Délorme for muscle rehabilitation is recommended.

CONGENITAL ANOMALIES OF THE KNEE JOINT

The common congenital anomalies encountered in the knee joint, which may require surgery, are a discoid meniscus and herniations of the posterior capsule. Congenital subluxation of the joint and absence of the patella are less common variations

Discoid Meniscus

In our series of cases, the discoid meniscus occurred in 2.4 per cent. This anomaly involves the external meniscus more frequently than the internal. Symptoms are most apt to occur in children or young adults, and may come on with or without injury. The outstanding complaint is a painful snapping *sensation*, accompanied by an audible click, thud, or jar when the knee is flexed and extended. A palpable tender mass may be felt along the joint line, and its prominence is exaggerated as the knee is brought from a flexed position to extension. The roentgen films are usually negative, but may show abnormal widening of the lateral compartment in the anteroposterior view. The *treatment* of this condition

is surgical. The approach is made with one of the usual incisions (Fisher; Jones). The discoid member may be found intact or split (Fig 8) and occupies a large portion of the space between the femur and tibia. Excision is accomplished without difficulty, and the results are uniformly good, except, perhaps, for some residual relaxation of the joint.

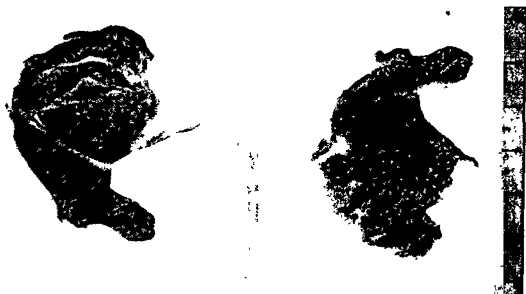


Fig 8 —Congenital discoid lateral meniscus, superior and inferior surfaces.

GANGLIA OF THE KNEE JOINT

Ganglia develop more frequently from the knee joint than from any other joint save the wrist. The majority comes from an outpocketing of the joint capsule itself, but some develop from tendon sheaths, particularly the semitendinosus and semimembranosus tendons. The ganglia originating from the joint itself may be discussed under three separate headings, according to etiology.

Baker's Cyst (Congenital Ganglia) This condition occurs in children, is regarded as being due to a congenital weakness in the posteromesial capsule, and manifests itself by a swelling varying in size from that of a walnut to a small orange over the mesial aspect of the popliteal space. It is relatively painless, but may be associated with mild discomfort in the joint, increased fluid in the knee, and some limitation of motion, particularly in flexion. It represents a true hernia of the joint, and it always occurs at the weakest point in the popliteal space, i e., mesially between the mesial gastrocnemius head and the mesial hamstring tendons

Treatment: Excision of the mass, with ligation of the pedicle, gives relief.

The Traumatic Ganglion This condition usually follows some form of twisting injury to the knee, and is frequently associated with internal derangement, i e., semilunar cartilage injury The herniation is almost always in the mesial portion of the popliteal space. Symptoms are those of discomfort in the knee, particularly in the posterior aspect. Examination reveals a visible and palpable mass in the popliteal space, more noticeable in extension of the knee, and down along the

border of the inner gastrocnemius head. There is also, as a rule, moderate synovitis in the knee.

Treatment: If symptoms are more than mild, excision of the mass is indicated.

The Degenerative Ganglion. This occurs in elderly people and is associated with a degenerative or hypertrophic arthritis of the knee. Usually symptoms are not severe, but if they are disabling, excision of the ganglionic mass should be done. Recurrence of the ganglion is not unusual in this type, because of the poor ability of the tissues to heal satisfactorily at the pedicle after excision.

CYSTIC DEGENERATION OF THE SEMILUNAR CARTILAGE

Cyst formation is rarely associated with the internal meniscus, but is not uncommon in connection with the external; there were 8 such cases in our series, 1 of the internal, and 7 of the external semilunar cartilage. There may be a history of injury, and at operation one frequently finds a transverse split in the cartilage opposite the cyst at the periphery (Fig. 9A). The symptoms are not those of



Fig. 9A.—Cyst of the lateral semilunar cartilage associated with transverse split in the meniscus.

severe internal derangement, but are characterized by an indefinite, vague pain, more or less localized to the side of the knee, made worse by walking, and often painful at night after the patient has been on his feet during the day. Th [illegible] at examination are characteristic; the ha [illegible] from that of a cherry to a walnut, usually [illegible] at the level of, and dissecting its way inferior or superior to the joint line. It is tender to strong pressure. There may be associated atrophy of the thigh muscles due to prolonged misuse of the extremity, and the synovial fluid in the joint may be moderately increased. Motions of the knee, however, are usually normal, and the stability of the joint is, as a rule, not disturbed.

is surgical. The approach is made with one of the usual incisions (Fisher; Jones). The discoid member may be found intact or split (Fig 8) and occupies a large portion of the space between the femur and tibia. Excision is accomplished without difficulty, and the results are uniformly good, except, perhaps, for some residual relaxation of the joint.



Fig. 8—Congenital discoid lateral meniscus, superior and inferior surfaces

Ganglia of the Knee Joint

Ganglia develop more frequently from the knee joint than from any other joint save the wrist. The majority comes from an outpocketing of the joint capsule itself, but some develop from tendon sheaths, particularly the semitendinosus and semimembranosus tendons. The ganglia originating from the joint itself may be discussed under three separate headings, according to etiology.

Baker's Cyst (Congenital Ganglia). This condition occurs in children, is regarded as being due to a congenital weakness in the posteromesial capsule, and manifests itself by a swelling varying in size from that of a walnut to a small orange over the mesial aspect of the popliteal space. It is relatively painless, but may be associated with mild discomfort in the joint, increased fluid in the knee, and some limitation of motion, particularly in flexion It represents a true hernia *of the joint, and it always occurs at the weakest point in the popliteal space,* i e., mesially between the mesial gastrocnemius head and the mesial hamstring tendons

Treatment. Excision of the mass, with ligation of the pedicle, gives relief.

The Traumatic Ganglion. This condition usually follows some form of twisting injury to the knee, and is frequently associated with internal derangement, i e., semilunar cartilage injury. The herniation is almost always in the mesial portion of the popliteal space. Symptoms are those of discomfort in the knee, particularly in the posterior aspect. Examination reveals a visible and palpable mass in the popliteal space, more noticeable in extension of the knee, and down along the

border of the inner gastrocnemius head. There is also, as a rule, moderate synovitis in the knee.

Treatment: If symptoms are more than mild, excision of the mass is indicated.

The Degenerative Ganglion. This occurs in elderly people and is associated with a degenerative or hypertrophic arthritis of the knee. Usually symptoms are not severe, but if they are disabling, excision of the ganglionic mass should be done. Recurrence of the ganglion is not unusual in this type, because of the poor ability of the tissues to heal satisfactorily at the pedicle after excision.

CYSTIC DEGENERATION OF THE SEMILUNAR CARTILAGE

Cyst formation is rarely associated with the internal meniscus, but is not uncommon in connection with the external; there were 8 such cases in our series, 1 of the internal, and 7 of the external semilunar cartilage. There may be a history of injury, and at operation one frequently finds a transverse split in the cartilage opposite the cyst at the periphery (Fig. 9A). The symptoms are not those of



FIG 9A—Cyst of the lateral semilunar cartilage associated with transverse split in the meniscus.

severe internal derangement, but are characterized by an indefinite, vague pain, more or less localized to the side of the knee, made worse by walking, and often painful at night after the patient has been on his feet during the day. The findings at examination are characteristic, the hard swelling (Fig. 9B), varying in size from that of a cherry to a walnut, usually lies just anterior to the lateral ligament, at the level of, and dissecting its way inferior or superior to the joint line. It is tender to strong pressure. There may be associated atrophy of the thigh muscles due to prolonged misuse of the extremity, and the synovial fluid in the joint may be moderately increased. Motions of the knee, however, are usually normal, and the stability of the joint is, as a rule, not disturbed.

Usually the only reason for operative removal of the cystic meniscus is pain, and this varies from time to time. If, however, there is an associated split of the meniscus, there probably will be "catching" or "locking" of the knee, which are definite indications for operation. The meniscus and cyst are removed as one.



FIG 9B.—Cyst of the lateral meniscus.

OSTEOCHONDRITIS DISSECANS

This condition may occur in any joint, but is most common in the knee, and begins without definitely known injury. The age at onset is usually in puberty or early adolescence, and it is more common in boys than in girls. The cause of osteochondritis dissecans is not well understood, but presumably it is due to an infarct involving the subchondral bone and resulting in interruption of the blood supply to the involved area of bone and articular cartilage, which in time produces aseptic necrosis of the involved portion of the articular surface. This area may remain intact, but usually becomes loose and creates abnormal friction between the joint surfaces or may become completely detached, and move about in the joint as a "loose body." The lesion is most common in the internal femoral condyle, secondly, in the patella, and thirdly, in the external femoral condyle. We have not seen it involve the tibia.

Symptoms are those of pain and swelling, occurring usually without a history of injury, and accompanied on examination by a fullness of the knee, increased surface temperature, possibly tenderness over the involved articular surface, and restriction of motions at the extreme. Roentgenograms early in the disease may be completely normal, but as the area of aseptic necrosis develops, a line of demarcation will appear around the involved region (Fig. 10).

Treatment. Unless the surgeon believes that the "loose body" is either free in the joint or is attached by only a small pedicle, creating marked friction in the

joint, surgery is not indicated. In fact, to excise one of these areas over which there is intact articular cartilage continuous with the joint surface is to do harm. Therefore, in most cases, conservative treatment is indicated, namely, quadriceps [illegible]. Whether these exercises, external support, a [illegible] hey may remain areas of "aseptic necrosis" eve[illegible] quiescent *if severe injury* to the joint can be avoided. Attempts to revascularize the avascular fragment by the use of fine multiple drill holes through the area into the subchondral bone have not been successful. If the "body" becomes free in the joint, then removal is indicated.



FIG 10.—Osteochondritis dissecans.

OSTEOCHONDROMATOSIS

Osteochondromatosis is a condition in which multiple cartilaginous loose bodies develop apparently from the synovial lining of the joint without known cause, and is responsible for symptoms of pain, swelling, limitation of motion, and, at times, locking of the joint. A typical case is described:

J H C (No. 580537), male, aged 27, was seen in June 1947, complaining of a gradual onset of pain, swelling, and limitation of motion of the right knee in 1943, four years previously. There was no history of injury. Examination revealed a markedly swollen knee, synovial thickening, and a feeling of loose bodies, or synovial tabs in the quadriceps pouch. These were tender, as was also the internal joint line. The external joint line and popliteal space were negative. The patella moved freely. There was a fixed flexion deformity of 40°, with further flexion to 60°. Attempted motions beyond this range were very painful. Roentgenograms of the knee were normal, except for increased soft tissue thickening. Possible diagnoses were synovial tumor, a nonspecific inflammatory process, tuberculosis, or osteochondromatosis

Operation was done on July 2, 1947. Through a median parapatellar incision, the

joint was found to contain multiple loose cartilaginous bodies (Fig. 11), and approximately 40 cc. of thick turbid fluid, apparently containing some fibrin. The synovia was moderately thickened and congested There was mild chondromalacia of the inferior surfaces of the patella. The semilunar cartilages and cruciate ligaments were intact. The articular surfaces of the tibia and femur were normal All visible loose bodies were removed, and the joint thoroughly irrigated with saline solution Postoperative convalescence was uneventful. Patient was given rehabilitation exercises, and was last seen March 12, 1948, eight months after operation, at which time he had a normal range of motion, good stability, no increase in joint fluid, and only ¼ in. atrophy of the thigh.



FIG 11 —Chondromatosis, more than 100 cartilaginous loose bodies removed from the knee joint

THE PATELLA

The patella, which is the largest sesamoid bone in the body, forms an important part of the extensor mechanism of the knee joint, but because of its anatomic relationship with the femoral condyles, it frequently plays a part in mechanical derangement of the joint. The patella normally rides in the groove between the condyles and creates a constant source of friction against the articular surfaces. Also, because of its superficial position over the knee, it is subjected to repeated trauma in the routine activity of the extremity. It is, therefore, not surprising that as age progresses, or as trauma is sustained by the knee, articular changes in the knee occur first between the patella and the femur Bennett, Waine, and Bauer demonstrated this fact clearly in their study of knee joints at various decades of

life. These mechanical changes are discussed under Chondromalacia and Hypertrophic Changes of the Patella.

Chondromalacia of the Patella

This condition presumably develops from localized injury to the articular surface of the bone. Nutrition to the articular cartilage is interrupted, and it develops a shredded appearance, *with multiple striations in*, and softening of, the cartilage in the center of the area, down to the subchondral bone (Fig. 12).



FIG. 12 —(A) Chondromalacia of the pa
the articular surface of the patella, and
I
astrable by roent-
edian parapatellar
incision. The articular surface of the patella is turned upward demonstrating an extensive area of chondromalacia in the central portion There was thinning of the cartilage over the inner aspect of the medial femoral condyle The synovia was markedly thickened and congested. Roentgenograms were entirely normal.

(Reproduced by permission of *Surgery, Gynecology & Obstetrics.*)

It is most common in young males, and the symptoms are gradual in onset and are characterized by discomfort in the knee, moderately increased fluid, slight limitation of motion, and, most important of all, tenderness under the articular surface of the patella. Chondromalacia of the patella may be associated with other pathologic findings, such as an injured semilunar cartilage, or osteochondritis dissecans of a femoral condyle.

Roentgenographic Findings In the early cases, the roentgen rays of the patella are usually negative. As the disease progresses, however, and the subchondral bone is involved, the articular surface of the patella may show some irregularity by roentgenogram. In the series of 11 cases of chondromalacia in 126 consecutive knee arthrotomies, the roentgen rays of the patella were negative in all.

There may be, however, associated loose bodies demonstrable by roentgen ray.

Treatment. The form of treatment to be employed is determined by the severity of symptoms in the individual case. If the symptoms are mild and cause only an occasional disability of the knee, even though the diagnosis of chondromalacia of the patella may be reasonably certain, operation should not be carried out until the patient has been observed over a period of time, and then only if symptoms increase in severity. During this time, exercises to maintain strength in the quadriceps muscles should be carried out. In the patient with moderately severe symptoms with an occasional locking, or rather frequent catching of the knee which may be followed by pain, swelling, and stiffness, operation is probably indicated. These knees should be explored through a parapatellar incision, and if the area of disintegrated cartilage is of moderate size, complete excision of the area should be carried down to the bone. Loose cartilaginous bodies throughout the knee should be searched for. If an extensive area of chondromalacia is found, covering essentially the entire surface of the patella, or if there is marked eburnation and thickening of the patella, the fourth and final stage of the process, one of two operative procedures is indicated. (1) patellaplasty, consisting of horizontal resection of approximately four-fifths of the patella with interposition between the bony surfaces of the patella and femoral condyle of a flap of synovia, turned up from the infrapatellar region, or (2) extirpation of the patella. It has not been our practice to excise the patella unless the changes are extremely advanced. Other authorities, however, have advocated excision of the patella in chondromalacia, notably Harris of Toronto.

Hypertrophic Patella

The hypertrophic patella may represent an advanced stage of chondromalacia of the patella, or may be a part of a generalized arthritic process in the knee joint. It usually occurs in the elderly adult, and is associated with other changes in the joint, such as thickening of the synovia, spur formation and eburnation of the articular cartilage, and partial disintegration of the semilunar cartilages. Symptoms are those of pain in the knee and recurrent swelling, probably a flexion deformity of the knee, limitation of motion, and pain aggravated by walking, particularly on stairs or over uneven surfaces. Examination reveals, possibly, flexion deformity of the knee of 15 to 20° and a thickened joint throughout, the thickening being confined particularly to the patella, which is broadened as well. Motion between the patella and the underlying femoral condyle is usually markedly restricted There may be locking of the knee if there are associated loose bodies in the joint. Symptoms are increased by activity.

Roentgenographic Changes. The roentgenograms reveal not only hypertrophic changes throughout the joint, but also marked changes in the patella, consisting in spur formation, thickening and broadening of the bone. There may be demonstrable osteocartilaginous loose bodies by roentgenogram.

Conservative treatment consists of rest, local applications of heat, quadriceps exercises, and external support in the form of an elastic knee-cap, attention to shoes, and, possibly, arch supports.

Surgical Treatment. Here again a choice lies between extirpation of the patella and a patellaplasty. We have preferred patellaplasty, because we believe it is

essential to maintain the continuity of the extensor mechanism of the knee joint if it is at all possible. The knee is, therefore, explored through a long parapatellar incision and the patella is turned so that it faces upward. Loose bodies are searched for, and the remains of the disintegrated semilunar cartilages are removed. The patella is thinned to "wafer" size (Fig. 13) with a saw, and a flap of fat and synovia is turned upward from the infrapatellar region and sutured to the quadriceps tendon. As a rule, hypertrophic spurs on the femoral condyles are not



A B C

Fig. 13.—(A) Lateral roentgenogram, before operation, (B) 18 months after operation, (C) 28 months after operation.
(J Bone & Joint Surg., 32A:542, 1950)

removed, particularly if they are covered with articular cartilage. We believe that to remove these spurs simply creates a raw, bony surface which in time will cause adhesions between the extensor apparatus and the underlying femur. Postoperative treatment consists of early and vigorous quadriceps exercises to restore and maintain muscular strength in the quadriceps muscles. Crutches should be used until muscular strength is sufficient to maintain complete extension of the knee.

Recurrent Dislocation of the Patella

One of the common and severely disabling mechanical difficulties of the knee is recurrent lateral dislocation of the patella. In general, there are two types, (1) the so-called congenital type, and (2) the traumatic. The recurrent dislocation which is referred to as the congenital type is due to the anatomic arrangement of the patella, and its relationship to the lower extremity as a whole. Predisposing anatomic defects are a severe knock knee, or a defective lateral femoral condyle, both of which may allow the patella to be displaced lateral to the outer femoral condyle during flexion and extension of the knee.

If the condition exists in combination with a severe knock knee, it may be necessary to do a supracondylar osteotomy of the femur to correct the valgus position of the knee, and thus restore the normal line of pull on the patella through the

There may be, however, associated loose bodies demonstrable by roentgen ray.

Treatment The form of treatment to be employed is determined by the severity of symptoms in the individual case. If the symptoms are mild and cause only an occasional disability of the knee, even though the diagnosis of chondromalacia of the patella may be reasonably certain, operation should not be carried out until the patient has been observed over a period of time, and then only if symptoms increase in severity. During this time, exercises to maintain strength in the quadriceps muscles should be carried out. In the patient with moderately severe symptoms with an occasional locking, or rather frequent catching of the knee which may be followed by pain, swelling, and stiffness, operation is probably indicated. These knees should be explored through a parapatellar incision, and if the area of disintegrated cartilage is of moderate size, complete excision of the area should be carried down to the bone. Loose cartilaginous bodies throughout the knee should be searched for If an extensive area of chondromalacia is found, covering essentially the entire surface of the patella, or if there is marked eburnation and thickening of the patella, the fourth and final stage of the process, one of two operative procedures is indicated: (1) patellaplasty, consisting of horizontal resection of approximately four-fifths of the patella with interposition between the bony surfaces of the patella and femoral condyle of a flap of synovia, turned up from the infrapatellar region, or (2) extirpation of the patella. It has not been our practice to excise the patella unless the changes are extremely advanced. Other authorities, however, have advocated excision of the patella in chondromalacia, notably Harris of Toronto.

Hypertrophic Patella

The hypertrophic patella may represent an advanced stage of chondromalacia of the patella, or may be a part of a generalized arthritic process in the knee joint. It usually occurs in the elderly adult, and is associated with other changes in the joint, such as thickening of the synovia, spur formation and eburnation of the articular cartilage, and partial disintegration of the semilunar cartilages Symptoms are those of pain in the knee and recurrent swelling, probably a flexion deformity of the knee, limitation of motion, and pain aggravated by walking, particularly on stairs or over uneven surfaces. Examination reveals, possibly, flexion deformity of the knee of 15 to 20° and a thickened joint throughout, the thickening being confined particularly to the patella, which is broadened as well. Motion between the patella and the underlying femoral condyle is usually markedly restricted There may be locking of the knee if there are associated loose bodies in the joint. Symptoms are increased by activity.

Roentgenographic Changes The roentgenograms reveal not only hypertrophic changes throughout the joint, but also marked changes in the patella, consisting in spur formation, thickening and broadening of the bone There may be demonstrable osteocartilaginous loose bodies by roentgenogram.

Conservative treatment consists of rest, local applications of heat, quadriceps exercises, and external support in the form of an elastic knee-cap, attention to shoes, and, possibly, arch supports.

Surgical Treatment. Here again a choice lies between extirpation of the patella and a patellaplasty. We have preferred patellaplasty, because we believe it is

RUPTURE OF THE QUADRICEPS AND PATELLAR TENDONS

Rupture of the quadriceps tendon is produced by the same mechanism as is *fracture of the patella, i.e., by a sudden contracture of the quadriceps muscle with* the patient bearing weight, with the knee flexed at approximately 30° to 60°, the tendon is pulled away from the patella. This injury occurs characteristically in older adults and may be partially due to a degenerative process in the tendon. The diagnosis is made by an analysis of the type of trauma sustained and by local examination, which reveals a palpable defect in the quadriceps tendon just above the patella, and inability of the patient to lift the extended knee against gravity. Treatment calls for immediate suture of the tendon to the patella with strong silk, fascia, or wire, which is placed through a drill hole in the patella and interwoven in the quadriceps tendon. Early active exercises can be started in 10 days in order to restore elasticity of the quadriceps muscle. It is well to have the patient wear a caliper brace when ambulatory, which will allow an increasing amount of flexion of the knee as normal flexibility of the quadriceps muscle is restored. Return of function should be accomplished in three months and the brace discarded.

Rupture of the patellar tendon is a rare occurrence, but occasionally the tibial tubercle is pulled off by the patellar tendon attachment. This is not likely to occur if the bone of the tibia is normal, but the writer has seen it happen twice in patients with Paget's disease. Treatment should consist of immobilization of the leg for six weeks in plaster of paris with the knee in complete extension.

FRACTURES OF THE TIBIAL TABLES.

A fairly common and disabling fracture of the knee joint is the "bumper" or "fender" fracture involving the tibial condyles and resulting in damage to the ligamentous support of the joint.

Mechanism of Injury. The common type of trauma is sustained from the bumper of a moving automobile which strikes the patient on the outer side of the knee. The fracture is also frequently sustained by a fall from a height in which the patient lands with *knee flexed and adducted. As the knee is adducted and flexed,* the lateral femoral condyle is driven downward against the lateral tibial table, which is compressed and fractured, and the internal collateral ligament, and possibly the cruciate ligaments, are strained or ruptured. Various combinations of injury to bone and ligaments may occur (Figs. 4 and 14)

Symptoms and Signs are those of severe knee joint damage Pain is usually generalized, but may be most marked over the stretched internal collateral ligament. There is usually flexion deformity and extreme pain on any attempted motion. Careful palpation is frequently not possible because of pain, but tenderness is usually most marked over the lateral tibial table or over the internal collateral ligament

Roentgenographic Findings Roentgenograms in the anteroposterior, lateral, and oblique views should be taken of both knees after the injured knee is gently brought into extension.

Treatment Although there may be increased synovial fluid and blood in the knee joint, aspiration is rarely necessary unless the joint is painfully tense. If there is a minimal fracture of the lateral tibial table, and if the ligaments are not badly

quadriceps muscle. For the defective lateral condyle, probably the best form of *surgical treatment is to transplant mesially the tibial tubercle with the patellar* tendon attachment

The traumatic type of recurrent dislocation of the patella usually results from injury to the mesial joint capsule, but there may be an associated genu valgus which predisposes to repeated displacements. If recurrences are frequent and severe, operation should be carried out. Probably the best procedure is a combina*tion of freeing the lateral expansion plication of the mesial joint capsule and transplantation of the tibial tubercle, along with the patella tendon, the width of* the tubercle and slightly downward.

FRACTURES INVOLVING THE KNEE JOINT

Fractures of the Patella

Fractures of the patella may be transverse, linear, or comminuted.

Mechanism of Injury. The usual fracture of the patella is sustained by an indirect pull produced when the quadriceps muscle suddenly contracts with the knee flexed about 30° to 60°, and the bone is actually pulled apart. It fractures transversely across the middle, or at times in the upper and lower portions. Frequently, the lateral expansions are torn and there is extensive hemorrhage in and about the joint

Examination reveals swelling and possible discoloration of the anterior aspect of the joint, usually a palpable defect at the fracture site, and inability of the patient to lift the extended leg against gravity. Roentgen rays demonstrate more or less separation of the patellar fragments, with soft tissue swelling

Treatment If there is marked reaction in the joint, inability of the patient to lift *his leg, and evidence by roentgen ray of more than moderate separation of the* main fragments, we must assume that the lateral expansions are lacerated, and if so, operative repair of the bone and the joint capsule is indicated. Various types of repair have been advocated, but probably the best is one in which the patella is sutured through drill holes with heavy silk, fascia, or wire, and the lateral expansions (synovia and ligament) are repaired with silk. *It is well to protect the knee after operation in a bivalved plaster cylinder until the wound is healed,* then to begin active non-weight-bearing exercises in flexion and extension The split plaster is gradually discarded at the end of six weeks, and the use of crutches is indicated until there is 90° or more of motion in flexion. This indicates that good flexibility of the quadriceps muscle has been restored and refracture is unlikely.

If the fracture is at the upper or lower pole of the patella, leaving a small fragment of bone attached to the tendon, it is better to excise the small fragment and suture the tendon to the large remaining fragment, as described above. Comminuted fractures of the patella are usually sustained by a direct blow, and are best treated by primary excision of all fragments and suture of the patella and quadriceps *tendons*

A few surgeons have advocated primary excision of the patella after all major fractures (Brooke), but we cannot hold with this thesis, and believe that it is better to repair the usual fractures by suture, if good apposition of fragments can be obtained.

periosteally back to the tibiofibular ligament. Usually the semilunar cartilage is displaced downward into the fracture line, and therefore it must be removed in order to visualize the fracture and also to effect reduction. The displaced lateral portion of the tibial table is osteotomized and turned outward, and the depressed fragments elevated to their normal position. It may be necessary to remove some of the small fragments of articular cartilage which have little chance of survival. The main lateral fragment or fragments are then apposed to the tibia and secured by a long bolt with a tap on the inner end to maintain reduction. Extensive comminution of the fracture makes the procedure difficult. If this is the case, a tibial bone graft removed from the anterior portion may be driven under the joint surface to preserve the tibial plateau. We have not found it necessary to suture any of the internal lateral ligaments. In only one case in our series was there severe damage to the cruciate ligaments, which resulted in luxation of the knee, and a poor functional result was obtained because of instability of the joint, in spite of the fact that the fracture was well reduced by operation. If the mesial condyle, rather than the lateral, has been displaced, the bayonet incision must be placed on the inner aspect of the knee, in which case care should be exercised to preserve the internal saphenous nerve.

Whether plaster immobilization or suspension in a hinged splint should be used after operation is optional. We believe that if the fracture has been well stabilized by the bolt, suspension is sufficient. Early exercises can be carried out in the splint and at the end of six weeks' period, the patient is allowed to walk on crutches and with little weight-bearing in a light hinged brace to prevent any tendency to valgus deformity of the knee.

If the fracture is a simple, noncomminuted one, it is possible that manipulation and compression, followed by plaster, will be sufficient. For the minor displacements or depressions, or both, manipulation and plaster fixation may improve the situation. As in all fractures of weight-bearing joints, delayed weight-bearing must be practiced. Crutches must be used for a period of two to six months, depending on the severity of the injury. Any tendency to valgus position of the knee must be prevented by the use of a hinged brace and Thomas heel.

Fracture of the Tibial Spines

The third rather common fracture directly involving the knee is that of the tibial spines, which is sustained by a twisting injury in which the spines are pulled off by the cruciate ligaments. Treatment by immobilization for six weeks in a plaster casing from toes to groin will usually allow sufficient healing, unless the fragments are widely separated, in which case operation should be done and the spines sutured into position.

Fracture of the Femoral Condyles

Fracture of the femoral condyles may enter the knee joint, and it is desirable to restore as accurately as possible the normal contour of the joint surface. Therefore, if manipulation or traction does not accomplish this end, open reduction through the long parapatellar or quadriceps tendon dividing incisions should be carried out. Usually the fractures can be stabilized with bolts or screws and plates are unnecessary

damaged, immobilization may not be necessary. Such an injury can be successfully treated by support from a pillow splint for a few days, combined with hot fomentations and early non-weight-bearing exercises. Crutches must be used for at least six weeks in the minimal fracture. For the severely depressed fracture of the lateral condyle, it is difficult to understand how such a fracture can be replaced by manipulative means with any degree of accuracy. Therefore, we usually

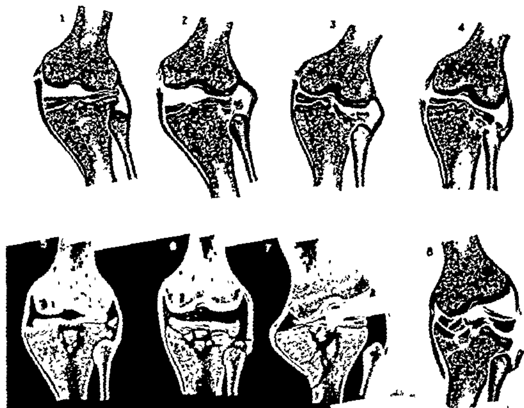


FIG 14.—Types of fracture of the condyles of the tibia and head of the fibula dependent on the mechanism of injury (1) Flexion and adduction of the knee: strain of the internal lateral ligament and compression of the external semilunar cartilage (2) and (3) Flexion and adduction of knee. injury to the internal lateral ligament and probably the cruciate ligaments with compression of the external semilunar cartilage and comminuted fracture of the lateral tibial condyle (4) In addition to the injuries in (1), (2), and (3) there is also fracture of the fibula head. (5) and (6) Bursting fracture of both condyles, usually sustained by falling from a height. (7) and (8) Flexion and abduction of the knee injury to the external lateral ligament and probably the cruciate ligaments, also injury to the internal semilunar cartilage and comminuted fractures of the internal tibial condyle

(Reproduced by permission of *Surgery, Gynecology & Obstetrics.*)

employ the following operation The lateral aspect of the knee is exposed with a bayonet incision, beginning just posterior to the lateral femoral epicondyle, about 3 in. above the joint line, and curving forward at the joint line, and down along the lateral portion of the tibial crest for 4 in The joint is opened anterior to the external lateral ligament with a curved incision and posterior to the ligament and popliteus tendon with a perpendicular incision. The upper tibia is exposed sub-

patella. From this point, the approach swings both medial and lateral to the patella, dividing the expansion of the quadriceps tendon together with the capsule of the joint. Below the patella, the approach is extended downward through the capsule of the joint on both sides of the patellar tendon, to the level of the articular surface of the tibia. The synovial membrane is divided parallel with the lines of the capsular incision. The patella, together with the patellar tendon, is reflected distally and the knee is flexed to 90°, thus exposing the lower end of the shaft of the femur and the major portion of the knee joint. The medial or lateral condyle of the femur is exposed by retraction. In closing the wound, the patellar flap is restored to its normal position, and the quadriceps tendon and capsule of the knee joint are closed with interrupted sutures.

THE FISHER INCISION

This incision begins just anterior to the femoral epicondyle, either mesial or lateral, and curves downward and forward along the joint line to the level of the patellar tendon. The skin and subcutaneous tissues are divided, and the lateral expansion exposed. On the inner aspect of the knee, one may encounter the terminal branches of the internal saphenous nerve, which must be retracted and preserved. The lateral expansion is then incised in the same line, and the synovia is likewise opened. This gives a thorough view of the anterior portion of the internal semilunar cartilage, the synovia, the infrapatellar fat pad, and the articular surfaces of the medial, femoral, and tibial condyles, and cruciate ligaments, but does not give an adequate view of the external semilunar cartilage, the external tibial or femoral condyles, or the articular surface of the patella. This incision is preferred by some surgeons for removal of damaged semilunar cartilages. It is not possible, however, to remove adequately the posterior portion of a semilunar cartilage through this incision without danger to the articular surfaces of the tibia and femur. Therefore, it is used only when it is believed the injury is confined to the mesial or anterior portions of the meniscus. When there is doubt about the diagnosis, some more adequate approach should be used.

THE ROBERT JONES APPROACH

This begins mesial or lateral to the border of the patella, curves down to the joint line, and backward along the joint line, to the level of the collateral ligament. The quadriceps expansion and the synovia are divided in the same line, and the anterior portion of the joint exposed. Through this incision, the damaged semilunar cartilage can be removed, except for the posterior portion. This incision is used largely for removal of damaged menisci, and should be employed in cases comparable to those in which the Fisher approach might be used.

THE COMBINED ANTEROPOSTERIOR INCISION

This was described by the writer in 1935, and utilizes a skin incision similar to that advocated by Fisher, but begins ⅜ in posterior to the epicondyle, curves downward and forward to the joint line, and to the patellar tendon. On the mesial side of the knee, the branches of the internal saphenous nerve *must be identified* and preserved. There are always two, and sometimes three, of these branches. If they are divided, painful neuromas may form. The anterior capsular *incision*

SURGICAL APPROACHES TO THE KNEE

The choice of incision for any operation on the knee joint depends greatly on the preoperative diagnosis, and the certainty with which the lesion requiring surgery can be localized. If, for instance, the surgeon is convinced that he is dealing with an uncomplicated meniscus injury, he is justified in using one of the more restricted incisions, but if there is doubt as to the localization of the disease or injury, a more adequate exposure must be gained. Any approach must give sufficient exposure to avoid damage to the articular surfaces of the femur, tibia, or patella.

The Median Parapatellar Approach

This approach is used as a utility incision, and through this kind of incision more can be done than through any other approach to the knee, unless the quadriceps or patellar tendons are divided. It begins approximately 3 in. above the patella, directly in the midline, and is carried down, passing ½ in. medial to the patella, and curving lateral to the level of the tibial tubercle. The lateral expansion is incised, and dissection carried upward between the quadriceps tendon and the vastus internus muscle, and down to the medial border of the patella tendon. The synovia is incised and dissection carried sufficiently upward and downward to allow the patella to be turned. Through this incision, the following structures can be viewed: the synovia; the articular surfaces of the tibia, femur, and patella; the mucosal ligament; the cruciate ligaments; the infrapatellar fat pad; the intercondylar notch; the internal semilunar cartilage. By freeing the patellar tendon somewhat, and retracting the patella further laterally, the external semilunar cartilage can be visualized, but with some difficulty. This is not a good approach for removal of the external semilunar cartilage, unless wide exposure is obtained, nor is it as good for removal of the internal semilunar cartilage as are the usual curved incisions on the medial aspect of the knee, but through this incision, biopsies can be made, fusions and arthroplasties are often done, also removal of loose bodies.

The Midline Incision

The midline incision directly over the mid-portion of the patella is preferred by some surgeons for repair of a fractured patella. It gives adequate exposure and through this incision the lateral expansion can be repaired, and the fractured patella sutured. The only objection to this incision is that it leaves a scar directly over the patella, which may be uncomfortable, particularly when the patient kneels.

The Anterior Quadriceps Dividing Approach

This approach, described by Coonse and Adams, is excellent for arthrodeses of the knee or for open reduction of badly comminuted fractures of the femoral condyles. A longitudinal parapatellar incision is made, and the anterior surfaces of the quadriceps tendon, patella, and patellar tendons are exposed. The quadriceps tendon is incised longitudinally in its center, from its musculotendinous junction downward to a point approximately ½ in. above the upper margin of the

patella. From this point, the approach swings both medial and lateral to the patella, dividing the expansion of the quadriceps tendon together *with the capsule* of the joint. Below the patella, the approach is extended downward through the capsule of the joint on both sides of the patellar tendon, to the level of the articular surface of the tibia. The synovial membrane is divided parallel with the lines of the capsular incision. The patella, *together with the patellar tendon, is* reflected distally and the knee is flexed to 90°, thus exposing the lower end of the shaft of the femur and *the major portion of the knee joint*. The medial or lateral condyle of the femur is exposed by retraction. In closing the wound, the patellar flap is restored to its normal position, and the quadriceps tendon and capsule of the knee joint are closed with interrupted sutures.

THE FISHER INCISION

This incision begins just anterior to the femoral epicondyle, either mesial or lateral, and curves downward and forward along the joint line to the level of the patellar tendon. The skin and subcutaneous tissues are divided, and the lateral expansion exposed. On the inner aspect of the knee, one may encounter the terminal branches of the internal saphenous nerve, which must be retracted and preserved. The lateral expansion is then incised in the same line, and the synovia is likewise opened. This gives a thorough view of the anterior portion of the internal semilunar cartilage, *the synovia, the infrapatellar fat pad, and the* articular surfaces of the medial, femoral, and tibial condyles, and cruciate ligaments, *but does not give an adequate view of the external semilunar cartilage, the* external tibial or femoral condyles, or the articular surface of the patella. This incision is preferred by some surgeons for removal of damaged semilunar cartilages It is not possible, however, to remove adequately the posterior portion of a semilunar cartilage through this incision without danger to the articular surfaces of the tibia and femur. Therefore, it is used only when it is believed the injury is confined to the mesial or anterior portions of the meniscus. When there is doubt about the diagnosis, some more adequate approach should be used.

THE ROBERT JONES APPROACH

This begins mesial or lateral to the border of the patella, curves down to the joint line, and backward along the joint line, to the level of the collateral ligament. The quadriceps expansion and the synovia are divided in the same line, and the anterior portion of the joint exposed. Through this incision, the damaged semilunar cartilage can be removed, except for the posterior portion. This incision is used largely for removal of damaged menisci, and should be employed in cases comparable to those in which the Fisher approach might be used.

THE COMBINED ANTEROPOSTERIOR INCISION

This was described by the writer in 1935, and utilizes a skin incision similar to that advocated by Fisher, but begins ⅜ in. posterior to the epicondyle, curves downward and forward to the joint line, and to the patellar tendon. On the mesial side of the knee, the branches of the internal saphenous nerve must be identified and preserved There are always two, and sometimes three, of these branches. If they are divided, painful neuromas may form. The anterior capsular incision

begins just anterior to the internal femoral epicondyle, and curves downward and forward along the joint line to the patellar tendon. The synovia is opened in the same manner. Through this opening, the semilunar cartilage can be freed anteriorly and then passed backward between the collateral ligament and the femur and out through a second perpendicular incision, posterior to the collateral ligament. This incision is useful in removing cartilages which are damaged, particularly in the posterior portions, and menisci which have undergone cystic degeneration. If it is used laterally, the cartilage is passed mesial to the popliteus tendon and the external collateral ligament, and brought out posterior to these two structures and removed.

The Posterior Approach

The most accessible part of the posterior aspect of the knee is toward the mesial side. A 3 or 4 in. linear incision is made on the posterior mesial aspect of the knee and carried down between the inner hamstring tendons and the inner head of the gastrocnemius The capsule of the joint is promptly encountered and may be opened readily. This approach is the best for drainage of the joint, and is also the most frequently used for removal of ganglia, because it is in the region of the knee joint that most herniations of the capsule occur.

The Bayonet Incision

This incision begins slightly above and posterior to the level of the femoral epicondyle and is carried downward to the level of, and forward along, the joint line, and down toward the anterior portion of the tibia for about 3 in. On the inner side of the knee, the branches of the internal saphenous nerve must be identified and preserved The capsule can be opened in the same line as the skin incision. This incision is useful when dealing with fractures of the tibial condyles, particularly the "bumper" or "fender" fracture of the lateral tibial table.

PAIN REFERRED TO THE KNEE

It must be remembered that all pain in the knee does not arise in the joint or directly from its supporting structures. It may be referred from the lower back, from the hip, or from the foot and ankle Low back disability may give only the symptoms of pain in the region of the popliteal space, and in hip joint disease, particularly in children, the sole symptoms may be pain along the mesial aspect of the knee joint A severely pronated foot or old traumatic arthritis of the ankle can cause not only pain in the knee, but swelling and limitation of knee motion as well It is, therefore, important to examine the joints above and below the knee before deciding as to the primary origin of the pain.

REFERENCES

Abbott, L C., et al Injuries to Ligaments of the Knee Joint *J. Bone & Joint Surg*., 26.503, 1944

Baker, W M. Baker's Cyst, Formation of Abnormal Synovial Cysts in Connection with Joints. *M Classics*, 5 805, 1941

Bennett, G E: Fascia for Re-enforcement of Relaxed Joints. *Arch Surg*., 13 655, 1926.

Bennett, G. E., and Shaw, M. B.: Cysts of the Semilunar Cartilages. *Arch. Surg.*, 33:92, 1936.

Boyd, H. B, and Hawkins, B. L.: Patellectomy; Simplified Technique. *Surg, Gynec. & Obst*, 86:357, 1948.

Brantigan, O. C., and Voshell, A. F.: *Mechanics of Ligaments and Menisci of Knee Joint. J. Bone & Joint Surg*, 26:793, 1944.

Bristow, W. R.: Internal Derangement of the Knee Joint (Hunterian Lecture). *J. Bone & Joint Surg.*, 17.605, 1935.

Brooke, R : Fractured Patellae: An Analysis of 54 Cases Treated by *Excision. Brit. M. J.*, 1:231, 1946

... ctured Patellae by Excision. A Study of Morphology and ... 1936-37.

... ondyles Involving *the Knee Joint. Surg., Gynec. & Obst*, 86:289, 1948

Cave, E. F.. Calcification in Menisci. *J. Bone & Joint Surg.*, 25.53, 1943.

Cave, E. F. Combined Anterior-Posterior Approach to the Knee Joint. *J. Bone & Joint Surg*, 17:427, 1935.

Cave, E. F., and Rowe, C R.: The Patella: Its Importance in Derangement of the Knee. *J. Bone & Joint Surg*, 32A.542, 1950

Cave, E F, and Staples, O. S. Congenital Discoid Meniscus; Cause of Internal Derangement of the Knee *Am J Surg*, *51* 371, 1941.

Cave, E F., Rowe, C. R., and Yee, L. B K.: Chondromalacia of the Patella. *Surg, Gynec. & Obst*, *81*:446, 1945

Cave, E F, Rowe, C. R., and Yee, L. B. K.: Selection of Cases for Arthrotomy of the Knee in an Overseas General Hospital, Two Year Follow-up Study. *J. Bone & Joint Surg*, 27 603, 1945.

Colonna, P. C. Osteochondromatosis of the Knee Joint *Surg., Gynec. & Obst.*, 53.698, 1931.

Coonse, K, and Adams, J. D New Operative Approach to the Knee Joint. *Surg., Gynec. & Obst*, 27 344, 1943

Cubbins, W. R, Callahan, J J, and Scuderi, C S: Cruciate Ligament Injuries Caused by Complete and Incomplete Dislocations, Early and Late Pathology, Symptoms, and Method of Repair. *Surg., Gynec & Obst*, *64*:218, 1937.

DeLorme, T L Restoration of Muscle Power by Heavy Resistance Exercises. *J. Bone & Joint Surg*, 27.645, 1945

DeLorme, T L, Schwab, R. S., and Watkins, A L Response of Quadriceps Femoris to Progressive Resistance Exercises in Poliomyelitic Patients *J Bone & Joint Surg*, *30(A)*. 834, 1948

Fairbank, T J Knee Joint Changes after Meniscectomy. *J. Bone & Joint Surg.*, *30(B)*.664, 1948

Fisher, A G. T. *Internal Derangements of the Knee Joint; Their Pathology and Treatment by Modern Methods* Ed 2. London H K. Lewis & Co, 1933

Gaillie, W E, and Lemesurier, A B.. Repair of Injuries to Posterior Crucial Ligament of the Knee Joint *Ann Surg*, 85 592, 1927.

Ghormley, R K, and Dockerty, M B · Cystic Myxomatous Tumors about the Knee, Their Relation to Cysts of the Menisci *J Bone & Joint Surg*, 25 306, 1943.

Groves, E W H The Crucial Ligaments of the Knee-Joint, Their Function, Rupture, and the Operative Treatment of the Same *Brit. J Surg*, 7.505, 1919-20.

Groves, E W H Operation for Repair of the Crucial Ligaments. *Lancet*, 2.674, 1917.

Haggart, G. E Synovial Cysts of the Popliteal Space, Clinical Significance and Treatment. *Ann Surg*, *118* 438, 1943

Harris, R T Personal Communication

Haxton, H · Patella Index in Mammals *J Anat*, 78 106, 1944.

Henderson, M S Injuries to Semilunar Cartilages of Knee Joint *Surg, Gynec & Obst.*, *51*.720, 1930.

Jones, H T: Loose Body Formation in Synovial Osteochondromatosis with Special Reference to Etiology and Pathology *J. Bone & Joint Surg*, 6.407, 1924.

begins just anterior to the internal femoral epicondyle, and curves downward and forward along the joint line to the patellar tendon. The synovia is opened in the same manner. Through this opening, the semilunar cartilage can be freed anteriorly and then passed backward between the collateral ligament and the femur and out through a second perpendicular incision, posterior to the collateral ligament. This incision is useful in removing cartilages which are damaged, particularly in the posterior portions, and menisci which have undergone cystic degeneration. If it is used laterally, the cartilage is passed mesial to the popliteus tendon and the external collateral ligament, and brought out posterior to these two structures and removed.

THE POSTERIOR APPROACH

The most accessible part of the posterior aspect of the knee is toward the mesial side. A 3 or 4 in linear incision is made on the posterior mesial aspect of the knee and carried down between the inner hamstring tendons and the inner head of the gastrocnemius. The capsule of the joint is promptly encountered and may be opened readily This approach is the best for drainage of the joint, and is also the most frequently used for removal of ganglia, because it is in the region of the knee joint that most herniations of the capsule occur.

THE BAYONET INCISION

This incision begins slightly above and posterior to the level of the femoral epicondyle and is carried downward to the level of, and forward along, the joint line, and down toward the anterior portion of the tibia for about 3 in. On the inner side of the knee, the branches of the internal saphenous nerve must be identified and preserved The capsule can be opened in the same line as the skin incision This incision is useful when dealing with fractures of the tibial condyles, particularly the "bumper" or "fender" fracture of the lateral tibial table.

PAIN REFERRED TO THE KNEE

It must be remembered that all pain in the knee does not arise in the joint or directly from its supporting structures. It may be referred from the lower back, from the hip, or from the foot and ankle. Low back disability may give only the symptoms of pain in the region of the popliteal space, and in hip joint disease, particularly in children, the sole symptoms may be pain along the mesial aspect of the knee joint A severely pronated foot or old traumatic arthritis of the ankle can cause not only pain in the knee, but swelling and limitation of knee motion as well It is, therefore, important to examine the joints above and below the knee before deciding as to the primary origin of the pain.

REFERENCES

Abbott, L. C, et al: Injuries to Ligaments of the Knee Joint *J. Bone & Joint Surg*, 26,503, 1944
Baker, W M. Baker's Cyst, Formation of Abnormal Synovial Cysts in Connection with Joints *M. Classics*, 5 805, 1941
Bennett, G E · Fascia for Re-enforcement of Relaxed Joints *Arch. Surg*, 13 655, 1926

Arthrodeses

ALAN DeFOREST SMITH, M.D.

ARTHRODESIS OF JOINTS has been found to be applicable to so many varied conditions and has proved itself to be so useful that it has become one of *the most frequently employed operations in orthopedic surgery.* In order to limit this discussion within reasonable bounds the application of this operation to the extremities only will be presented, because the usefulness and importance of spine fusion, which is no more than an arthrodesis of the joints of the spine, has become so great as to warrant a separate monograph. Although at first thought the deliberate destruction of a joint and abolition of all motion in it may seem to be a backward procedure and one to be avoided whenever possible, an analysis of the results will demonstrate that often it leads to an improvement in function not to be gained in any other way. Relief from pain and the arrest of disease are other important accomplishments which may be set down in its favor.

One of the first uses to which arthrodesis was put was the stabilization of joints over which control had been lost through paralysis resulting from lesions of the central nervous system, chief of which is poliomyelitis. Friedreich's ataxia, the cerebral palsies, and neurotrophic joints are other conditions which may be mentioned in this group, although they are less common. Loss of muscle power from peripheral nerve injuries also calls at times for joint stabilization. Attempts often have been made to redistribute muscle power by transplants and such operations play an important role in the rehabilitation of poliomyelitis patients and the victims of peripheral nerve injuries Usually the remaining power is not sufficient to achieve success, however, without the aid of stabilization, which in most cases must be done in addition to the transplant, in order to obtain a good result. Stability may be obtained also by braces, but relieving the patient of the necessity for using these heavy, cumbersome, and unsightly objects is one of the finest achievements of this operation.

Another important end which often may be gained only by obliteration of the affected joint is the relief of pain in various forms of arthritis. The one which first comes to mind in this connection is the osteo-arthritic hip in older individuals, which so often is seriously disabling. In some stiff painful joints due to rheumatoid arthritis this also is true. Although in this disease care must be taken not to stiffen a joint when loss of motion in the opposite one is liable to take place with serious impediment to locomotion. This does not apply, however, to the wrist. The result of arthrodesis of a subtalar joint, the seat of arthritis from an imperfectly reduced fracture of the os calcis, or of an ankle following a malunited fracture, usually is highly successful.

The arrest of tuberculosis in a joint after arthrodesis, which was demonstrated

Jones, R., and Smith, S. A.. On Rupture of the Crucial Ligaments of the Knee, and on Fractures of the Spine of the Tibia *Brit J. Surg.*, *1*·70, 1913.

King, D : Function of the Semilunar Cartilages *J Bone & Joint Surg*, *18*:1069, 1936.

King, D.. Healing of the Semilunar Cartilages. *J. Bone & Joint Surg*, *18*.333, 1936.

Last, R J. Some Anatomical Details of the Knee Joint *J Bone & Joint Surg*, *30(B)*.683, 1948.

Lipscomb, P R, and Henderson, M. S Internal Derangements of the Knee. *J A M.A*, *135* 827, 1947

MacAusland, W. R Study of Derangement of the Semilunar Cartilages Based on 850 Cases *Surg, Gynec. & Obst*, *77* 141, 1943.

McMurray, T P: The Diagnosis of Internal Derangements of the Knee, in *The Robert Jones Birthday Volume* London H. Milford, 1928

Mauck, H P. New Operative Procedure for Instability of the Knee. *J Bone & Joint Surg*, *18* 984, 1936.

Murray, C R. Complicating Factors in the Treatment of Injuries to the Menisci of the Knee Joint. *Am J. Surg*, *55* 262, 1942

Palmer, I On Injuries to Ligaments of the Knee Joint, Clinical Study *Acta chir. Scandinav*, (supp 53), *81*.3, 1938

Palmer, I Ten Operated Cases of Injuries to the Crucial Ligaments in the Knee Joint *Acta chir Scandinav*, *79* 391, 1937

Smillie, I S The Congenital Discoid Meniscus. *J Bone & Joint Surg*, *30(B)*.671, 1948

Soto-Hall, R Traumatic Degeneration of the Articular Cartilage of the Patella. *J. Bone & Joint Surg*, *27* 426, 1945.

Voshell, A F., and Brantigan, O C Bursitis in the Region of the Tibial Collateral Ligament. *J Bone & Joint Surg*, *26*.793, 1944.

THE SHOULDER

The conditions which most often indicate arthrodesis are paralyses resulting from poliomyelitis and tuberculosis. A painful arthritis or damage from a severe fracture may occasionally be indications. Arthrodesis of the humeroscapular joint is one of the most satisfactory owing to the fact that a useful range of motion of the arm is retained even after obliteration of the joint. This seeming paradox arises from the fact that the scapula still can move upon the thorax, thus compensating for the loss of motion in the scapulohumeral joint.

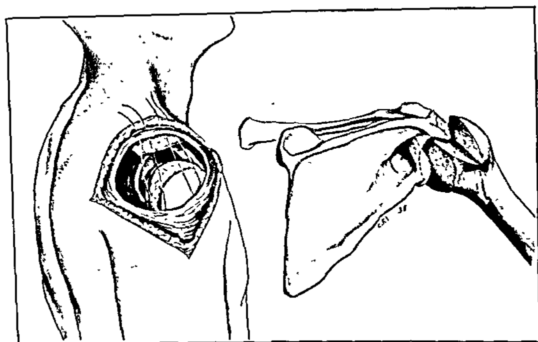


FIG 1.—Arthrodesis of the shoulder.
(Gill, A B : *J. Bone & Joint Surg*, *13*:287, 1931)

The position in which the humerus is fixed to the scapula is of the greatest importance. In order to take advantage of scapular motion there must be some abduction The degree is determined by the extent to which the scapula can rotate inward, thus allowing the arm to drop down to the body. Usually a greater degree of compensatory motion will develop in children, in whom a maximum of 70° of abduction of the humerus on the scapula may sometimes be allowed In adults this angle should be les
abducted the humerus should
between internal and external rotation.

A very important prerequisite to arthrodesis of the shoulder in paralysis due to poliomyelitis or other causes, is the presence of strong thoracoscapular muscles, including the trapezius, levator scapulae, rhomboids, and serratus anterior. Without these the scapula could not be activated and there would be no improvement in the function of the arm. Fortunately these muscles usually are spared, when the scapulohumeral group is affected.

by Hibbs, and which has revolutionized the treatment of that disease, is one of the greatest contributions to orthopedic surgery. Certainly no other means has been found of permanently arresting joint tuberculosis, and operative treatment will remain the only one that can accomplish this result, unless some antibiotic is discovered which is capable of destroying the bacillus. Streptomycin has been found to be a very useful adjuvant to arthrodesis in certain types of cases but alone it is inadequate and reliance still must be placed on fusion.

Another objective which may be attained by arthrodesis is the correction of deformity. This usually follows as a secondary result of the operation when it is used primarily to achieve some other purpose usually the stabilization of a joint. We frequently see this twofold gain in operations on the foot for instability and deformity resulting from poliomyelitis.

In many instances in which a joint has become painful, stiff, or deformed as a result of injury or arthritis, the choice between arthrodesis or arthroplasty must be made In favor of the former is the fact that it produces stability and eliminates pain and fatigue. In the care of a joint in the lower extremity these factors are of the greatest importance and usually will turn the balance in favor of arthrodesis. With a tuberculous infection this is mandatory and arthroplasty cannot be considered. The unfavorable results of fusion are stiffness and some degree of limp. These vary a good deal with the joint involved. In the shoulder, wrist, ankle, or subtalar joints there is none and the disability is minimal. In the hip the limp after fusion is not great and the disability is only moderate. The greatest degree of limp and inconvenience follows stiffening of the knee but, on the other hand, the result of arthroplasty of this joint is very uncertain The important point is that in the lower extremity, stability and freedom from pain and fatigue usually are more desirable than motion.

Arthroplasty, while theoretically superior to arthrodesis in many conditions, in that it preserves motion and at the same time aims to produce stability, frequently falls short of its purpose Either the range of motion is too small to be satisfactory, or there are apt to be some residual pains, weakness, and fatigue. There may also be a limp The patient's age, occupation, and general requirements must be taken into account and should determine to a large extent the choice of operation.

THE ACROMIOCLAVICULAR JOINT

The chief indication for arthrodesis is upward luxation of the clavicle after rupture of the coracoclavicular ligaments. Probably the easiest way in which to correct this is fusion of the clavicle to the acromion. This may be done by excising the articular cartilage and meniscus and placing Kirschner wires through the acromion and clavicle. There is no important restriction of motion of the shoulder following the operation

Painful arthritis of the acromioclavicular joint is best treated by resecting the outer end of the clavicle, distal to the coracoclavicular ligaments. This relieves pain and restores the motion which was impaired by pain.

resection may be indicated. Similarly in elbows which have been badly damaged and stiffened from fractures, or in ankylosis from arthritis, resection is likely to be the operation of choice.

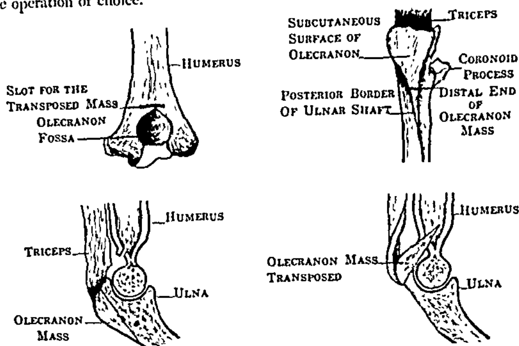


FIG. 2.—Fusion of the elbow
(Hallock, H., *J Bone & Joint Surg*, *14* 145, 1932.)

When it is decided to arthrodese the elbow because of tuberculosis the best method of accomplishing this has been devised by Hallock. It consists in removing a graft, including part of the olecranon process and some of the shaft of the ulna, reversing it, driving it into the humerus, and then fastening it to the ulna. The articular cartilage is first removed from the humerus and ulna. Usually the head of the radius is resected in order to maintain pronation and supination. The most useful position in which to stiffen the elbow usually is about 135° extension, although this may vary with the requirements of the individual.

THE WRIST AND HAND

The indications for arthrodesis of the wrist are similar to those in most other joints but, unlike the elbow, stability is here more important than mobility. A stiff wrist in optimal position is much more useful than one which is movable but in which the motion is not well controlled For this reason arthrodesis frequently gives the best result in poliomyelitis, in paralysis due to peripheral nerve injury, and in spastic paralysis. Resection does not serve here, as it sometimes does in tuberculosis of the elbow, and instead fusion always is indicated. When the wrist is badly disabled by rheumatoid arthritis or fractures, including those of the navicular, arthrodesis may be depended on to relieve pain, correct deformity, and restore function.

The optimal position for arthrodesis is slight extension, of from 5° to 15°. This gives the flexors of the fingers the best advantage and results in a stronger grip.

It has been demonstrated recently by Inman and Saunders and by Milgram that motion of the arm on the trunk may be materially increased after shoulder fusion by resection of the outer end of the clavicle. It is better to do this as a second step after arthrodesis has been accomplished.

There are many technics for fusing the shoulder. The choice depends somewhat on the age of the patient and the condition for which the operation is done. It is necessary to obtain glenohumeral union and the cartilage is removed from the head of the humerus and glenoid. Additional contact and fixation may be had by attaching acromial process to the humerus. In order to do this the acromion is partly divided at its base and turned downward, as described by Gill.

One of the difficulties in this procedure is the maintenance of the desired position of the humerus until firm union has occurred. Even though the arm is held in a plaster spica some of the abduction may easily be lost. To prevent this and provide greater security, internal fixation by means of one or more nails or screws through the head of the humerus into the glenoid, may be employed. This is less desirable in cases of tuberculosis of the shoulder, but there have been a number of successful instances in the case of metal fixation in tuberculous joints and we are not as averse to using it in these cases as we formerly were.

A difficulty in young children, in whom the humerus still is growing, is the preservation of the upper epiphyseal cartilage which contributes the larger amount of length to the bone. Shortening of the humerus is not as serious or important as it is in the femur or tibia, but still any considerable amount is to be avoided if possible. The shoulder can be fused without obliteration of the growth center but one cannot be as free in the treatment of the upper end of the humerus when this necessity is present, and in such cases the use of nails through the epiphyseal cartilage is unwise Rountree describes a method in which he places a tibial bone graft through the head into the glenoid in children. He states that there has been no interference with growth as a result.

The exposure of the joint and the carrying out of the operation are greatly facilitated by wide detachment of the deltoid from the acromion and clavicle. This may be done without fear of impairment of its function, since this is not necessary after the arthrodesis. It is necessary in most cases to maintain fixation in a plaster spica for at least four months after the operation and if there then is any doubt about the solidity of the fusion the support should be continued longer. Failure to do this has resulted in loss of abduction and impairment of the functional result.

THE ELBOW

Motion is important in the elbow in order to enable the placing of the hand in various desired positions. For this reason operations to restore or maintain mobility are used more frequently than arthrodesis. The chief indication for the latter is tuberculosis and the elbow is often fused in order to arrest that disease. Even in this condition, however, resection may be preferable to stiffening the joint if it is thought that the disease may be eradicated in this way. The elbow is the one joint in which a wide resection is permissible and may result in a useful joint The shortening which results is not a serious matter nor is the loss of stability. Thus in extensively involved joints in which it would be difficult to obtain bony union,

THE HIP

The hip joint is subject to many diseases and injuries which render it stiff, deformed, and painful. Because of its prime importance in the support of the body and in locomotion these lesions frequently cause much pain and severe disability. Arthrodesis is a solution to many of these problems because it provides stability [illegible] limp resulting from a stiff hip in optimal [illegible] the mobility of the lumbar spine the subject can sit without too much difficulty. In cases in which arthrodesis is elective, the added strain imposed on the lumbar spine by the stiff hip may cause backache in the presence of arthritis or certain anatomic variations. Under these circumstances arthrodesis may be contraindicated. Patients having a stiff hip often complain of some backache but usually this is not severe enough to be serious, or to make it outweigh the advantages of arthrodesis.

The choice between arthrodesis or arthroplasty frequently must be made. There is no doubt that retention of motion is desirable, but so frequently the result of arthroplasty falls short of the desired goal, either because of restricted motion, pain, or fatigue, that the patient is unable to lead a full active life and to take part in an occupation necessitating standing or walking. There is no doubt, in my experience, that as a rule arthrodesis gives a better over-all result when only one hip is affected [illegible] likely to be, as in rheumatoid arthritis, [illegible]. Bilateral stiff painful hips are so disabling that any degree of improvement is accepted with much gratitude and is a great contribution to the patient's welfare. On the other hand, tuberculosis is a positive indication for arthrodesis and the advisability of ever performing any arthroplasty on a hip that at any time has been the site of tuberculosis is very questionable.

The best position in which to stiffen the hip has been determined from experience in many cases. It is from 25° to 30° of flexion, neutral rotation, and no abduction. Efforts have been made to compensate for shortening of the extremity by fixing the hip in from 10° to 20° of abduction. This results in the tilting downward of the pelvis, a prominence of the opposite hip, and a compensatory lumbar scoliosis, and persons with a hip in this position almost invariably are displeased with the result On the other hand, a slight degree of adduction is not disabling although it is not to be sought. Flexion beyond 30°, while it makes sitting easier, causes a marked lordosis of the lumbar spine in the upright position and is liable to result in backache.

There are many technical difficulties in arthrodesing the hip joint and it is only in recent years that successful methods have been evolved. The problem is quite different in tuberculosis and in osteo-arthritis, the two most important conditions for which the operation is indicated. In tuberculosis bony ankylosis usually will take place if an adequate bridge of bone is constructed from the pelvis to the femur outside the joint, and it is undesirable to denude the head and acetabulum of cartilage. The situation is reversed in osteo-arthritis where the eburnated, poorly vascularized bone of the head and acetabulum is not conducive to ankylosis even after an extra-articular graft has been placed.

Albee devised an operation in which several struts of tibial bone were made to

Too much extension impairs the function of the hand, and flexion is never desirable. Care must be taken in cases of spastic paralysis not to extend the wrist too much for the spastic flexors may then prevent the fingers from extending. This applies also in Volkmann's ischemic paralysis in which the flexor muscles have become shortened.

Several methods have been described for arthrodesing the wrist, including various types of bone grafts. In the author's experience, simple removal of the articular cartilage from the radius and the several carpal bones has been sufficient. This is done through a dorsal midline incision. A choice may be made as to whether the proximal row of carpal bones only or the distal row also is to be included. *In traumatic arthritis, such as that following fracture of the navicular,* fusion of the proximal row to the radius is sufficient and some motion may be retained in the distal part of the joint. In tuberculosis, however, it is necessary to include all of the carpal bones as well as the joints between them and the metacarpals An exception should be made, when possible, of the joint between the first metacarpal and the greater multiangular because movement of the first metacarpal is very important to the function of the thumb. It has been found that in cases of spastic paralysis in which wrist fusion is done to overcome flexion deformity and give stability, the entire wrist must be fused in order to prevent recurrence of the deformity.

The wrist and forearm are immobilized in plaster following the operation. So much swelling of the hand and wrist occurs that it is necessary to split the plaster completely on both radial and ulnar sides. This should be done as soon as the plaster is applied, and the hand should be kept in an elevated position. Lack of rigid immobilization is not detrimental at first and the cast may be changed and a more closely fitting one applied at the end of two weeks.

It seldom is desirable to stiffen the metacarpophalangeal joints or those of the fingers The joint between the first metacarpal and greater multiangular is often the seat of a painful osteo-arthritis and when this is marked it may be necessary to do an arthrodesis In the description of wrist joint fusion the importance of not stiffening this joint was mentioned. However, when the arthrodesis is confined to the carpometacarpal joint, compensatory increase in motion often takes place in the joint between the multiangular and navicular.

In some cases of paralysis of the hand, usually the result of poliomyelitis, if it is not possible to substitute for the loss of the opponens pollicis by transplantation of some other tendon, it improves the hand greatly to fix the first metacarpal in the position of grasp, i e., a combination of opposition and slight abduction. This has been done by arthrodesing the carpometacarpal joint but a more certain result can be obtained by a strut graft between the first and second metacarpals. If the flexors of the thumb are also greatly impaired, arthrodesis of the metacarpophalangeal joint may be done in addition.

Should an injury or infection threaten the destruction with consequent stiffening of a phalangeal joint, it should be placed in partial flexion since this will give the most useful finger afterward.

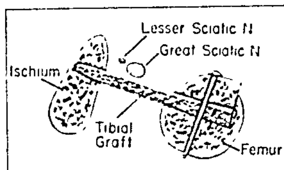


FIG 1.—Fusion of the hip Cross section showing fixation of the graft (Van Gorder, G W J *Bone & Joint Surg*, *31A* 717, 1949)



FIG 5—Roentgenogram made two and a half years after the Trumble operation. An error in diagnosis was made in 1942 when a cup arthroplasty was performed The operation was unsuccessful and the cup was removed A diagnosis of tuberculosis was established and iliofemoral fusion was attempted in 1943 The fusion was not successful A second attempt at iliofemoral fusion was made in 1944, this also failed and three sinuses developed. The patient was then sent to a sanatorium where a Trumble ischiofemoral arthrodesis was performed in November 1946 Note the graft has become hypertrophied and that the hip joint has fused. During her convalescence, a tuberculous lesion was discovered in the patient's spine and a spine fusion was carried out successfully At present, she is active and well and the three tuberculous sinuses have remained healed.

(Van Gorder, G W J *Bone & Joint Surg*, *31A*:717, 1949)

span the joint from the ilium to the trochanter. This was successful in accomplishing an arthrodesis in a number of cases but the method never became popular. In 1925 Hibbs and Haas independently reported a new method in which a graft was



FIG 3—Hip fusion operation by the Hibbs method

A Tensor femoris muscle divided.
B Vastus muscle divided
C Gluteus medius and minimus muscles which were cut through anteriorly and above trochanter
D In 1a, 2a, and 3a, trochanter turned up with lower end under iliac bone flap
E Raw bone superior surface of neck of femur.
F Head of femur in acetabulum
G Capsule of joint

taken from the trochanter and adjacent shaft, and after being reversed so that the sharp shaft portion was upward, was driven into a slot in the ilium near the acetabular margin, the lower end making contact with the trochanter. This operation has been highly successful, especially in tuberculosis of the hip, and still fre-

placed closer to the joint. All of these methods have their indications in properly selected cases. There are some cases of tuberculosis in which the head and neck of the ilium are so extensively diseased that it is not possible to employ a graft from the ilium to the trochanter. In order to meet this situation Trumble employed a tibial graft from the ischium to the femur. This was done through a posterior approach in which the ischium, femur, and sciatic nerves were well exposed. Van Gorder reported a series of cases in which this operation was used with a high percentage of success. The operation has met with favor and now is being used widely in this type of case.



FIG. 7.—Arthrodesis of the hip joint. Anteroposterior view after insertion of nails, two from inside the ilium.
(Smith, A. DeF., and Baab, O. D.: *J Bone & Joint Surg*, 31A:727, 1949)

Brittain used the same principle in placing an ischiofemoral graft, but instead of obtaining a good exposure by the posterior incision, placed the graft blindly through a lateral incision after doing a subtrochanteric osteotomy. This has been successful in many cases, but the chief objection to the operation is that the sciatic nerve cannot be seen and is in danger of being injured by the chisel or the graft. For this reason the Trumble operation seems preferable. Bosworth has described an ischiofemoral graft which, like Brittain's, is introduced blindly and therefore has the same objections.

quently is used. It may be combined with removal of the cartilage from the upper part of the head or acetabulum, without dislocation of the head, but this is not always necessary and was not a feature of the operation as originally described. The graft must be placed in sound bone in the ilium, even though this necessitates placing it at some distance above the acetabulum. If this precaution is not observed, the graft is liable to absorb, fracture, or fail to unite to the ilium. Firm contact with the femur may be assured by a square nail driven through the graft



FIG 6 —Arthrodesis of the hip joint. Exposure of the joint. The quadriceps is detached from the anterior inferior spine of the ilium, and not at the point indicated
(Smith, A DeF, and Baab, O D · *J. Bone & Joint Surg*, *31A*.727, 1949.)

and upper part of the femur. Hibbs' attempt to preserve some blood supply to the graft by leaving the gluteus medius and minimus attached to it makes the operation much more difficult, and has not seemed to enhance the chance of success. It is the custom now to remove the muscle attachments completely Of course, if the greater trochanter is diseased, the operation is not applicable.

Harris and John Wilson have described operations in which iliac grafts are used instead of a trochanteric one. A tibial graft may be employed, differing from the Albee type in that only one, thicker and shorter, piece of bone is used and is

effects of prolonged immobilization in the latter group had dire effects upon the *growth and development of their extremities.*

ARTHRODESIS FOR OSTEO-ARTHRITIS OF THE HIP

An entirely different problem is encountered when one attempts to fuse a hip for painful osteo-arthritis. This condition is essentially the result of degenerative changes and there are found sclerotic bone with a poor blood supply, worn, fibrillated articular cartilage, completely missing in some areas and a thick fibrotic capsule. Although osteophytes are deposited around the margins of the joint, the conditions just described make the accomplishment of bony union between the femoral head and acetabulum difficult Reliance cannot be placed on an extra-articular graft alone because even though it unites, the fusion will not extend through the joint itself unless something more is done to bring this about Consequently the operation must include some interference within the joint. This may consist simply of removal of remnants of articular cartilage and some of the eburnated bone surfaces from the upper part of the joint, combined with some form of graft, either from the tibia, ilium, or of the Hibbs type. Such operations, however, have resulted in too many failures

The author has evolved a method which has produced a higher percentage of successful fusions. It is performed by an anterior Smith-Petersen incision with wide exposure of the superior and anterior parts of the capsule. The latter then is widely excised. In addition to affording a better exposure of the joint, this removes a thick, fibrotic barrier to the blood supply which is available from the overlying muscles. The head of the femur is dislocated and all cartilage is removed from the head and acetabulum. Multiple drill holes are made in these structures and the head is then replaced. Several long, square nails are then driven from the ilium into the head and neck of the femur A plaster spica usually is applied but in some cases may be omitted.

As previously stated, one may be assured of freedom from pain and fatigue when this operation is done for arthritis, whether it be caused by gradual degenerative changes, injury, or disease. It does result in some awkwardness in sitting, and a slight limp but neither of these objections is serious unless the patient is engaged in some occupation in which a greater range of flexion of the hip is necessary. Certainly for those having to stand or walk a good deal or those obliged to do heavy manual work, it is the treatment of choice, provided the other hip is not affected and the lumbar spine is free from arthritis.

Arthritis of the hip resulting from aseptic necrosis of the femoral head presents another difficulty, because the avascular head is a serious detriment to bone repair and usually must be removed Arthrodesis of the hip still is possible after disappearance of the head, but is more difficult. Either the greater trochanter may be denuded and fitted into a notch in the ilium or an ischiofemoral graft of the Trumbull type may be done. In this situation many prefer to do some reconstruction operation, or a modified arthroplasty

ARTHRODESIS OF THE HIP IN POLIOMYELITIS

Another indication for arthrodesis of the hip, which has not received as much consideration as it might, is the stabilization of the joint in cases of severe paral-

After any of these operations the hip is immobilized in a plaster spica until union is obtained. The Trumble operation is done with the patient in the anterior half of a plaster spica which is applied before operation. This has the great advantage of making it possible to place the hip in the desired position before the operation and of maintaining the position afterward. This always is a difficult matter if the spica is applied after the operation, and yet with the other methods of arthrodesis it is not practicable to carry out the operation with the hip immobilized in plaster.

The time necessary for the achievement of solid bony union varies greatly but is longer in cases of tuberculosis than in other conditions. The time is longer also in children than in adults Yu, in the study of a series of cases operated on at the New York Orthopaedic Hospital, found that the average time required for union in children was 18 months. This is an important point to remember and should deter one from reoperating too soon or of abandoning hope of success too early.

Whatever method is used, one must be prepared for a rather high percentage of failures in the first attempt to arthrodese a tuberculous hip. In a series studied at the New York Orthopaedic Hospital by Hallock and Toumey only 68.7 per cent were successful after the first operation. After a second and in some cases a third attempt, 87 2 per cent obtained a solid fusion. In certain cases, particularly those with abscesses and sinuses, and those in which the disease is very active, streptomycin seems to be of definite value in promoting healing and favoring union. It appears from studies by Bosworth, and by Smith and Yu, that we may safely operate on such cases with the help of streptomycin, without waiting an indefinite period for the disease to become quiescent. Such delay frequently is disastrous, resulting in marked destruction of the whole joint, incapacitating the patient for perhaps years, and subjecting him to the danger of dissemination of the disease in the meantime

Another objection to prolonged immobilization of the extremity in plaster is the effect on the calcification of the bones They become so seriously demineralized that fractures occur easily in the epiphyseal plates of the lower end of the femur or upper end of the tibia, resulting in cessation of growth. Gill described this condition and explained the frequent occurrence of serious growth disturbances in these cases It is our opinion that prolonged rest has been overdone in the treatment of bone and joint tuberculosis and that the patient's general health and resistance to the disease could be promoted better by effective operative immobilization of the joint and earlier ambulation.

The determination of the minimal age at which the hip can be successfully fused for tuberculosis is important. Some surgeons withhold the operation for an unnecessarily long time in young children in the belief that a fusion cannot be produced, or that if it is done, a serious disturbance of growth will result. The youngest patient upon whom the operation was done at the New York Orthopaedic Hospital was 14 months old. A fusion resulted, the disease was controlled, and he now has been under observation for more than 20 years. The extremity is well developed and is only 1½ inches short Numerous other children have been operated on successfully when under five years of age. The difference between their extremities and those of other children who in the past were treated conservatively is very enlightening. The destruction wrought by the disease and the

Arthroplasty of the knee joint has been attempted by many surgeons but has been less successful than in the hip joint The necessity of producing enough motion to be satisfactory and at the same time maintaining stability of a joint which is dependent almost entirely on ligaments for its integrity has been too great a problem in all but a few cases. It is possible often to relieve pain in an osteoarthritic knee by removing exostoses, doing a partial synovectomy, and sometimes excising the patella. This procedure frequently makes a fusion unnecessary and there is thus less occasion to resort to it than in similar involvement of the hip

Since the availability of streptomycin a number of attempts have been made to

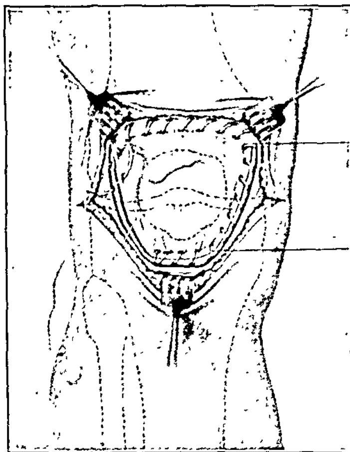


Fig 9—Technic of knee joint fusion—Hibbs method The periosteum of the patella has been sutured to that of the tibia, after which the capsule is closed.
(Hibbs, R. A *New York M J*, May, 1917.)

cure synovial tuberculosis of the knee by the use of this antibiotic, either with or without synovectomy. A few successes have been reported but there also have been failures. Years must elapse after the operation before one can be certain of curing a tuberculous knee with motion, and until the end results are proved in [illegible]

[illegible], may be stabilized by fixing the foot and ankle in equinus. This presupposes the presence of good hip extensors or, if they are absent, arthrodesis of the hip. It should be emphasized, however, that the hip and knee should not be arthrodesed on the

ysis resulting from poliomyelitis. It originally was done in cases in which the paralyzed hip had subluxated or completely dislocated. In them the effect on the stability of the extremity and the marked improvement in the gait was so striking that the operation then was done in cases in which there was extensive paralysis of the hip muscles without dislocation. Hallock has reported excellent results in a relatively small series of cases which should encourage a wider employment of the operation. In several of these cases in which there was a practically complete paralysis of the entire extremity, it was possible for the patient to walk well without any brace or other support, by combining the hip fusion with a pantalar arthrodesis of the foot and ankle. It was found that the hip fusion compensated for loss of the hip extensors, which usually are essential in order to make a fixed equinus of the foot stabilize a paralyzed knee It should be noted that in order for a hip fusion to be successful in these cases there must be good strength in the quadratus lumborum muscle.

ARTHRODESIS OF THE KNEE

In general, the same conditions which call for stiffening of the hip apply to the knee joint. It is the only proved treatment for tuberculosis and it sometimes is the only means of relieving pain and restoring the ability to walk in cases of painful arthritis of various types. It offers the only means by which the knee can be stabilized in severe cases of poliomyelitis in which the quadriceps is paralyzed.

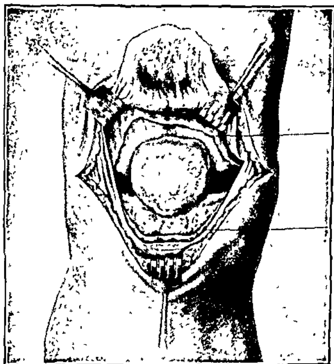


FIG 8 —Technic of knee joint fusion—Hibbs method The articular cartilage has been removed from the femur and tibia, and the patella has been mortised between them
(Hibbs, R. A · *New York M. J*, May, 1917.)

ually to increase, the deformity often occurring at the epiphyseal plate either of the tibia or femur. It is best in children, therefore, to arthrodese the joint in full extension.

The simplest means of arthrodesing the knee is to expose the joint through a curved transverse incision and then to remove just enough bone and cartilage from the femur and tibia to leave flat surfaces which fit accurately together. Contact is maintained more securely and union is promoted by using some kind of internal fixation. This may be done easily by two nails introduced from the femur into the tibia from each side in the form of an X. Bosworth advocates the use of one triflange nail, such as is used for fractures of the neck of the femur. Whatever kind of internal fixation is employed, it is best to use a plaster cast as well. Walking without weight-bearing may be started in from two to six weeks, depending on the solidity of the fixation and the pathologic condition of the joint.

Key and, more recently, Charnley pointed out the advantage of compression in promoting healing in arthrodesis of the knee. Charnley describes a device for producing this consisting of heavy wires passed transversely through the femur and tibia and joined by turnbuckles. By using this he obtained union after arthrodesing operations much faster than by the usual methods.

A special problem is presented in the case of children with tuberculous knees in whom it is desirable to do an arthrodesis before completion of growth. It is, of course, essential to avoid any damage to the epiphyseal cartilages. The articular cartilage is thick and the epiphyseal bone relatively thin. Obviously nails or wires which would transfix the growth cartilages must be avoided. For this type of case Hibbs devised an operation in which the articular cartilage is removed from the femur and tibia without sacrifice of any bone, and the patella then is mortised in between the femur and tibia. This can be done without exposing the epiphyseal cartilage. Hibbs preserved some of the anterior attachment of the patella, but to do so increases the difficulty of the operation considerably and it has been found possible to obtain a fusion just as well if the patella is completely detached and then denuded of cartilage.

It should be stated that in doing a fusion operation for tuberculosis of the knee, it is not necessary, and indeed it frequently is impossible, to remove all of the tuberculous granulation tissue from the synovial membrane or the bone.

ARTHRODESIS OF THE ANKLE

A number of various diseases, injuries, and degenerative changes necessitate or make advisable arthrodesis of the ankle. Among these are destruction of the joint by tuberculosis or other infections, osteo-arthritis, especially that following injury, and instability due to paralysis. The latter most frequently is the result of poliomyelitis but may follow peripheral nerve injuries. A fairly common indication is pain and stiffness in the ankle following a severe fracture in which adequate reposition of the fragments was not made. There is no substitute for an arthrodesis in relieving such patients from very disabling pain. Arthrodesis of the ankle often is combined with that of the subtalar joint of the foot in weakness caused by poliomyelitis. A surprisingly good gait may result from this combined procedure if the proper position of the foot and ankle has been secured.

same side, except possibly for tuberculosis. Fusion of the knee and ankle in the same leg is not necessarily disabling, especially if the extremity is short.

Another use for arthrodesis of the knee is to control the disintegration of the joint from trophic disturbances resulting from lesions of the spinal cord, of which tabes dorsalis is the most common. It sometimes is not realized that such knees can be arthrodesed and that the operation may be the only means of preventing complete disintegration and severe disability. Of course, it should be undertaken before the changes have become too marked.



Fig 10—Arthrodesis of the knee in a case of poliomyelitis, using the nails for internal fixation

The disturbance in gait resulting from a stiff knee is greater than in the hip. The pendulum swing of a stiff extremity is noticeable. The handicap of inability to flex the knee also is quite great The leg sticks out when the patient sits in a theater or a public conveyance and is quite annoying There are some occupations which cannot be carried on with a stiff knee These considerations are sufficient to deter some persons from having the operation for such elective conditions as stabilization. It is surprising however, that almost without exception those who have had the operation are pleased with the result and would not trade their stiff knees for braces

The best position in which to fuse the knee in an adult with extremities of approximately the same length, is in about 10° of flexion This results in a better gait and makes the leg less awkward in sitting. It has been found, however, that if this position is adopted in the case of growing children, the flexion is apt grad-

seems worth while to take a film on the operating table before the incision is closed.

Other methods of fusion have been described, including the use of a bone graft from the tibia into the talus. In the author's experience this has seldom been necessary and it has not been used because it makes the procedure unnecessarily complicated. The approach has been varied by going in from one side and removing a malleolus, which is later replaced. This also would seem to have little to recommend it in favor of the anterior approach.

It is possible to combine arthrodesis of the ankle with that of the subtalar joint. The best incision is a long anterolateral longitudinal one, similar to that used for the ankle alone, but prolonged farther down on the foot. It is surprising how well the ankle, talocalcaneal, talonavicular and calcaneocuboid joints may all be exposed through this one incision. It may have been employed elsewhere but the author first saw it used by Dr. Leon Lantzounis at the New York Orthopaedic Hospital. If it is necessary to do any carpentry in remodeling the foot, as in deformities from poliomyelitis, it is better to do the foot and ankle arthrodeses separately, because in these cases it is too difficult to carry out all of the exacting steps in both operations at one time.

Even though internal fixation has been used in the ankle joint, a plaster cast should be used extending from the toes to the mid-thigh. This may be left on for six weeks or may be changed at two weeks for a cast extending to the knee. Weight-bearing is not permitted until the end of the sixth week, at which time another snugly fitting cast is applied and worn until the end of the twelfth week.

ARTHRODESIS OF THE FOOT

Arthrodesis finds its greatest field of usefulness in the foot because deformities are here so frequent from the effects of poliomyelitis as well as from congenital causes. Less common are deformities from other diseases of the central nervous system, such as Friedreich's ataxia and certain forms of muscular dystrophy. Other reasons for using this operation on the foot are weakness of the ligaments causing a so-called flat foot, painful arthritis, tuberculosis of the tarsus, and traumatic arthritis due to fractures. In arthrodesing the joints of the foot not only can stability be attained but deformity can be corrected at the same time, thus accomplishing a twofold purpose.

Lateral motion in the foot takes place entirely in the subtalar joint, whereas flexion and extension occur almost exclusively in the ankle. The subtalar joint is a compound one comprising the talocalcaneal, which itself is composed of two separate facets, and the talonavicular Adduction and abduction of the forefoot take place in the so-called mediotarsal joint which is made up of the talonavicular and the calcaneocuboid joints. In order to eliminate all of the principal movements in the foot, therefore, it is necessary to stiffen all of these joints. This is spoken of as a triple arthrodesis.

If an arthrodesis is to be done without impairing the development of the foot, it must be undertaken after the bones have matured sufficiently so that removal of cartilage from contiguous surfaces will not sacrifice too much of the structure. This varies somewhat in different individuals but usually means that the minimal

In no joint is the position in arthrodesis of greater importance. The foot must be in enough equinus or plantar flexion to enable the patient to take off on the ball of the foot in walking If the ankle is stiffened with the foot at 90° this is not possible and walking will be most difficult and awkward The optimal position is from 95° to 105°, depending on the sex and the relative length of the legs. It is, of course, necessary to compensate by the height of the heel on the shoe for the angle at which the foot is set. Men, therefore, will be better satisfied with an equinus of from 95° to 100° and a relatively low heel. Women, on the other hand, usually will want a higher heel and, therefore, will be better pleased with an equinus of from 100° to 105°.

If the extremity on which the ankle arthrodesis is being done is shorter than the other, it usually will be advisable to increase the equinus a little in order to compensate for the shortening Another factor which influences the degree of equinus is instability of the knee joint. It has been pointed out that failure of the quadriceps to stabilize the knee may be compensated for by equinus of the foot, provided the hip extensors are adequate or a hip arthrodesis is done. In such cases the ankle should be arthrodesed at not less than 100° nor more than 105°.

It often is possible for a patient with a stiff ankle in optimal position to walk without any perceptible limp Usually there is a compensatory increase in motion in the subtalar joint and with the foot in slight equinus and a heel of the right height walking is unimpeded. These patients do not walk well, however, in their bare feet or in slippers without heels.

The danger of damage to an epiphysis in children, which was mentioned in the remarks on arthrodesis of the knee, is present in a still greater degree in similar operations on the ankle. Here the proximity of the lower epiphyseal cartilage of the tibia to the articular surface makes it very difficult to avoid injury to it during the operation. As a result growth may be stopped in the whole epiphysis or in part of it, usually anteriorly As a result the leg will be shorter, and in case of injury to the anterior part of the cartilage, a calcaneus deformity of the foot gradually will occur with most unfortunate functional results. For these reasons it is best to postpone arthrodesis of the ankle until growth is completed, or nearly so. An exception to this is tuberculosis of the ankle, where it is necessary to perform the operation without delay in order to control the disease. If this is not done it is probable that the epiphysis will be destroyed by the infection. One therefore must take the chance of operating.

The ankle is most easily exposed through an anterior longitudinal incision just lateral to the extensor tendons. The latter are retracted medially with the vessels and nerve The articular cartilage is removed with little or no bone, from the tibia, fibula, and talus. The space left between the malleoli and the talus after removal of the cartilage may be filled in with chips from the tibial metaphysis or from any other source, such as the bone bank.

The advantage of absolute fixation and firm contact which can be achieved by internal fixation applies to the ankle as well. This may be done simply by inserting one or sometimes two screws or nails from the tibia downward through the joint into the talus Since the exact position of fixation is so important, one must be sure that this has been attained when the screw is inserted So frequently has the position been found unsatisfactory in the roentgenogram taken after operation that it

on the lateral surface of the foot. Hoke removed the head and much of the neck of the talus and stressed the importance of correcting deformity by remodeling *the neck and head of the talus which were then replaced. The cartilage and* enough bone are removed from the other joints to assure good contact and correct other components of the deformity. This operation has been accepted widely and probably is the technic most often used in the United States.

Lambrinudi introduced a new idea in removing enough of the talus and reshaping it so that either foot drop or excessive dorsiflexion could be checked. This is intended for the correction of either equinus or calcaneus deformities without the necessity for arthrodesing the ankle or using bone blocks. The operation has been found useful by many surgeons but there have been instances of relaxation and instability of the ankle following its use and the operation has been accepted with reservations and has not met with universal approval.

Brewster advocates countersinking the talus into the other bones in such a way as to accomplish the same purposes as the Lambrinudi procedure. This also has met with limited approval and is used only in specially selected cases. It is the opinion of the author and the group which he represents that in the majority of cases of flail leg and foot, or in those cases of calcaneus or equinus deformity with lateral instability of the foot, a combined ankle and subtalar, or so-called pantalar arthrodesis, gives the best results.

An important point in correction of varus deformities due either to paralysis or congenital club feet is to make certain of overcoming all of the varus. Slight overcorrection is acceptable but even a slight degree of varus gives a poor result. In order to insure this point not only must bone wedges be taken from the joints but it frequently helps to divide the calcaneonavicular ligament from its insertion into the navicular. This may be done quite easily in the Hoke operation after removal of the talar head and neck without making a separate incision. It may be desirable also to *divide or lengthen the tendon of the posterior tibial if it is exerting an* unopposed pull upon the inner side of the foot.

If lengthening of the tendo achillis is necessary in conjunction with subtalar arthrodesis in order to correct equinus, the subtalar arthrodesis should be done first and the foot reshaped before the tendon lengthening. The latter may then be done at the same operation, but it is regarded as better practice in most cases to do it at a second operation about six weeks following the arthrodesis.

Tendon transplants may be desirable in conjunction with arthrodesis in order to balance and utilize to the best advantage what muscles remain. Even the most enthusiastic advocates of muscle transplantation state, however, that if there is lateral instability or deformity of the foot the muscle operations must be accompanied by an arthrodesis, because it rarely is possible otherwise to achieve a balance sufficiently exact, or to have enough residual power to give a strong, stable foot. In doing the combined operation of stabilization and transplantation, it nearly always is advisable to do the arthrodesis first and to follow this in six weeks or more by the tendon transplant. The operation of arthrodesis of the subtalar joint is a major one and if combined with any other procedure is apt to result in too much trauma, with danger to wound healing

Plantar flexion of the first metatarsal bone may be present with other deformities of the foot and it may be necessary to correct this by an osteotomy through

age is from 10 to 12 years. This must be disregarded in cases of tuberculosis in which arrest of the disease is the important factor. David Grice has recently reported a method of arthrodesis which he says has been successful in young children without impeding the subsequent growth of the foot. It consists in inserting tibial grafts across the sinus tarsi after the soft tissues have been removed from it. This blocks the motion in the subtalar joint without actually disturbing the joint surfaces.

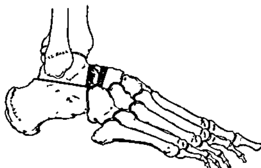


FIG 11.–Hoke arthrodesis of the foot.
(Patterson, R L, Parrish, F. F., and Hathaway, E N *J Bone & Joint Surg.*, 32A.1, 1950)

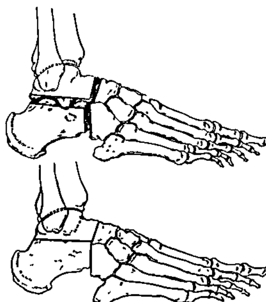


FIG 12.–Triple arthrodesis of the foot
(Patterson, R L, Jr, Parrish, F. F., and Hathaway, E N.. *J. Bone & Joint Surg*, 32A.1, 1950)

Arthrodesis of the subtalar joint first was made popular by G. D. Davis, who employed the operation for the stabilization of paralytic feet. His technic was improved by Ryerson who included the talonavicular and calcaneocuboid joints and was the originator of the so-called triple arthrodesis. Hoke introduced a new technic in which the three joints were approached through one oblique incision

too marked for treatment by supports and exercises but not so extreme as to require a complete subtalar arthrodesis. The procedure has the advantage of leaving unimpaired the motion in the subtalar and mediotarsal joints. It is successful in well selected cases, if the technic is carefully followed. A well molded plaster cast is worn for about eight weeks, at which time a metal arch support is substituted for it.

REFERENCES

Albee, F. H.: Extra-articular Arthrodesis of Hip for Tuberculosis, with Report of 31 Cases *Ann. Surg*, 69 104, 1929

Bosworth, D. M. Knee Fusion by Use of 3-Flanged Nail. *J Bone & Joint Surg.*, 28 550, 1946.

Bosworth, D. M Femoro-ischial Transplantation *J. Bone & Joint Surg*, 21.38, 1942.

Bosworth, D. M., Della Pietra, A., and Farrell, R F: Streptomycin in Tuberculous Bone and Joint Lesions with Mixed Infection and Sinuses. *J Bone & Joint Surg.*, 32A:103, 1950.

Brewster, A. H: *Countersinking Astragalus in Paralytic Feet New England J. Med*, 209:71, 1933

Brittain, H A.: Ischiofemoral Arthrodesis. *J Bone & Joint Surg.*, 30B:642, 1948.

Brittain, H. A.. Ischiofemoral Arthrodesis *Brit J Surg*, 29.93, 1941.

Charnley, J C.: Positive Pressure in Arthrodesis of the Knee Joint. *J. Bone & Joint Surg.*, 30B.478, 1948.

Davis, G. Wedge-shaped Resection of the Foot for Relief of Old Cases of Varus *New York M J*, 56 379, 1892.

Gallie, W E Arthrodesis of the Ankle Joint. *J Bone & Joint Surg*, 30B.619, 1948.

Gallie, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis. *J. Bone & Joint Surg*, 25 731, 1943.

Gill, A. B New Operation for Arthrodesis of Shoulder *J. Bone & Joint Surg.*, 13 287, 1931.

Gill, G. G: Cause of Discrepancy in Length of Limbs Following Tuberculosis of Hip in Children, Arrest of Growth from Premature Central Closure of Epiphyseal Cartilages about Knee *J. Bone & Joint Surg*, 26 272, 1944

Grice, D. Subastragalager Arthrodesis with Slot Grafts for Correction of Paralytic Feet in Children, Read at Meeting of the American Orthopedic Association, May 26, 1950.

Haas, S L.. Extra-articular Bone-graft Treatment for Tuberculosis of Hip Joint, with Special Study of Primary Failures of Fusion *J Bone & Joint Surg*, 15 743, 1933.

Hallock, H. Surgical Stabilization of Dislocated Paralytic Hips, End Result Study. *Surg, Gynec & Obst*, 75 721, 1942

Hallock, H: Fusion of Elbow Joint for Tuberculosis, a New Technique and Report of 3 Cases. *J. Bone & Joint Surg*, 14 145, 1932

Hallock, H., and Toumey, J. W, Jr. Hip Joint Tuberculosis Treated by Fusion Operation, an End Result Study of 170 Unselected Cases *J A M A*, 103.1836, 1934

Harris, R I.. Arthrodesis of Hip Joint, New and Simple Operation *S Clin North America*, 23.1412, 1943.

Hibbs, R A. Treatment of Tuberculosis of Joints of Lower Extremities by Operative Fusion. *J Bone & Joint Surg*, 12 749, 1930

Hibbs, R A. A Preliminary Report of 20 Cases of Hip Joint Tuberculosis Treated by an Operation Devised to Eliminate Motion by Fusing the Joint. *J. Bone & Joint Surg*, 8 522, 1926.

Hibbs, R. A: Tuberculosis of the Knee Joint in the Adult in Which Operations Were Done Eliminating Motion by Producing Fusion of the Femur and Tibia, a Report of 5 Cases from the Service of the Orthopaedic Hospital. *New York State J. Med*, 105.922, 1917.

Hoke, M. Operation for Correction of Extremely Relaxed Flat Feet. *J. Bone & Joint Surg*, 13.773, 1931.

Hoke, M: An Operation for Stabilizing Paralytic Feet. *J. Orthop. Surg*, 3.494, 1921.

the base of the first metatarsal shaft or arthrodesis of the first metatarsocuneiform joint This may be done safely at the time of the subtalar arthrodesis.

A limited arthrodesis of the calcaneotalar joint may be indicated in such conditions as deformity or arthritis following fracture of the os calcis in which the talonavicular and calcaneocuboid joints are not involved. This usually is done through a lateral incision but Gallie has described a method of introducing a tibial graft as a mortise through the joint from a posterior approach, which is simple and is said to be effective.

Arthrodesis of the talonavicular joint alone for the cure of flat or weak feet is advocated by some surgeons. It is somewhat easier to do than a complete triple arthrodesis, but the fixation thus secured cannot be as strong as though all three joints were included, although the limitation of motion resulting from the stiffening of this one joint is for all practical purposes just as great. It would seem therefore to have no real advantage over the complete operation.

It is the practice to apply a plaster cast extending from the toes to the mid-thigh after a subtalar arthrodesis Since the foot usually swells a good deal, it is advisable to split the cast over the dorsum of the foot and ankle, except for a narrow strip over the toes. The cast may be removed at the end of two weeks and a shorter one extending to the knee applied after removal of the sutures. The result of the operation should be checked by roentgenograms before application of the second cast in order that any displacement of the bones may be corrected if necessary by manipulation. Weight-bearing in a cast usually is started at the end of six weeks and the plaster is removed at the end of 12 weeks.

MIDTARSAL AND ANTERIOR TARSAL ARTHRODESIS

Some cases of cavus without lateral deformity may be treated by removal of a wedge through *the mediotarsal or talonavicular and calcaneocuboid joints.* This simplifies the operation, but it does not result in any greater mobility than would a complete subtalar arthrodesis. In a few selected cases in which the degree of cavus is not too great a wedge may be removed from the navicular and cuneiform and from the cuboid, anterior to the mediotarsal joint. This preserves the motion in the most important joints of the foot.

NAVICULOCUNEIFORM ARTHRODESIS

Hoke is the author of the operation for arthrodesis of the naviculocuneiform joint for the correction of certain cases of weak foot He noted that a study of roentgenograms of some cases of weak, pronated feet revealed that there was a sag between the navicular and cuneiforms in the standing position. This suggested that the foot might be strengthened by stiffening this joint. In addition to removal of the articular cartilage from the navicular and the first and second cuneiforms, a key of bone, taken from the tibia, is placed in a slot in the navicular and first cuneiform. The joint is locked with the foot in its normal position, i e, with the longitudinal arch restored If the calf muscle is contracted the tendo achillis must be lengthened at the same time.

The operation is intended for moderately severe cases of weak feet which are

Inman, V. T., Saunders, J. B. deC. M., and Abbott, L. C. Observations on Function of *Shoulder Joint. J. Bone & Joint Surg*, *26* 1, 1944

Key, J. A. Positive Pressure in Arthrodesis for Tuberculosis of the Knee Joint *South M. J.*, *25* 909, 1932.

Lambrinudi, C.: New Operation on Drop-foot. *Brit. J. Surg.*, *15*:193, 1926.

Milgram, J. E.: Technical Notes on Reconstructing Poliomyelitic Upper Extremity Deformities *Bull Hosp Joint Dis.*, 9.55, 1948.

Rountree, C. R.: Fusion of the Shoulder Joint in Children, Utilizing Autogenous Bone Graft, Read at Meeting of the American Orthopedic Association, May 19, 1949.

Ryerson, E.. Arthrodesing Operations on Feet *J. Bone & Joint Surg*, *5* 453, 1923.

Smith, A. DeF., and Baab, O. D.: A Technique for Arthrodesis of the Hip, Read at the Annual Meeting of the American Orthopedic Association, Colorado Springs, May 18, 1949; *J. Bone & Joint Surg*, *31A*·727, 1949.

Smith, A. DeF., and Yu, H. I.: Streptomycin Combined with Surgery in the Treatment of Bone and Joint Tuberculosis. *J.A.M.A.*, *142*:1, 1950.

Trumble, H. C.. Method of Fixation of Hip Joint by Means of an Extra-articular Bone Graft. *Australian & New Zealand J. Surg*, *1*:413, 1932

Van Gorder, G. W. · Trumbull Operation for Fusion of the Hip *J. Bone & Joint Surg*, *31A*: 717, 1949

Wilson, J. C.: Operative Fixation of Tuberculous Hips in Children, End Result Study of 23 Patients from Orthopaedic Department of Children's Hospital. *J. Bone & Joint Surg*, *15* 22, 1933.

Index